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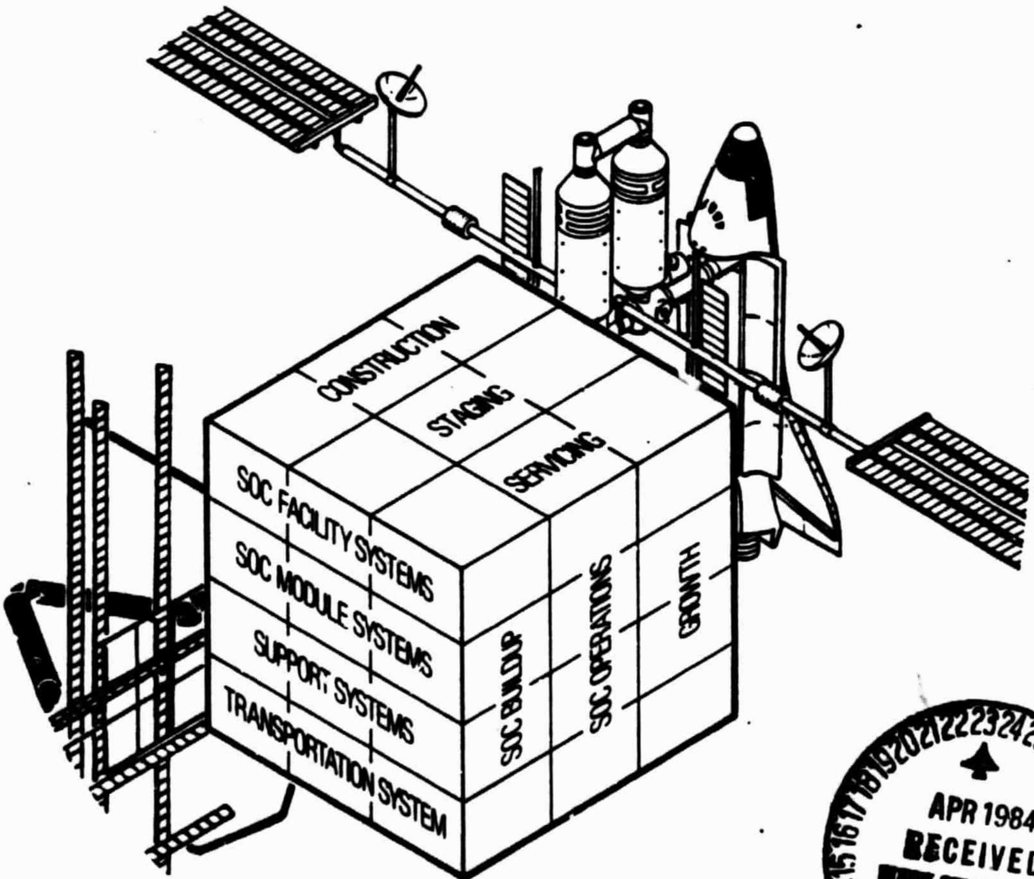
SPACE OPERATIONS CENTER — SHUTTLE INTERACTION STUDY (NAS9-16153)

MONTHLY PROGRESS REPORT NO. 3

OCTOBER 1980



Space Operations and Satellite Systems Division

Rockwell International

SOC/SHUTTLE INTERACTION STUDY

THIRD MONTHLY PROGRESS REPORT

September 19, 1980 - October 24, 1980

SECTION I. SUMMARY

A. Progress

During this reporting period the majority of the effort has been concerned with Task 4.0, SOC Resupply and Fuel Transfer.

The Task 2.0, Berthing and/or Docking efforts associated with the runaway jet terminal closure condition, docking clearances, and SPAR subcontract initiation were also performed during this period.

Task 1.0 - No further effort is planned for this task.

Task 2.0 - The investigation to verify that the docking module concept interface location will provide clearance between the orbiter and the module being docked in the most adverse condition was performed to complete the action item from the 30 July 1980 meeting. A minimum 5" clearance was determined for a worst case condition.

An investigation was also performed to determine if the extraction of payloads from the orbiter would be more advantageous if the orbiter were positioned in other than the nominal orientation. The results of this effort indicated that satisfactory clearance existed for the extraction and transport of payloads to various positions on the SOC while the orbiter was in the nominal orientation. The transportation path of the payloads was more devious but not beyond the capability of the SOC RCM. Consequently, no docking interface rotation capability would be required.

The subcontract documentation was sent to SPAR for their concurrance on 24 October 1980. The start of the runs is anticipated to be early in November.

Task 3.0 - Lighting requirements for the SOC assembly process leading to the definition of a lighting concept has been initiated. The analysis to determine the impacts to the SOC G&C system during the SOC assembly sequence while the modules are in an untended mode has also been initiated.

Task 4.0 - The deployment, transport, and exchange procedures for the SOC logistics module and for logistics modules/cradles envisioned to support both the flight support facilities operation and the space construction operation have been developed. In all cases the use of a holding and positioning aid device was determined to be the most desirable arrangement for the parking/holding of the modules during this exchange operation.

An analysis was also performed to determine the capability/feasibility of transporting eight crew members in the orbiter to and from the SOC. Two arrangements were defined for this operation; (1) with the airlock in the orbiter cabin, and (2) with no airlock in the cabin.

OTV propellant transfer concepts effort has been initiated to define line routing, distribution, and line connection arrangements.

Task 5.0 - The determination of flight support facilities concepts has been initiated. A number of options have been identified and are being developed and analyzed.

The identification of flight support servicing functions has also been initiated incorporating the definition of a MOTV as indicated in the September 1980 monthly progress report.

B. <u>Planning</u>

Figure 1 shows the planned schedule of task activities of the next reporting period. The principal efforts will be associated with the berthing simulation effort conducted by SPAR, the untended SOC module analysis, the pro-

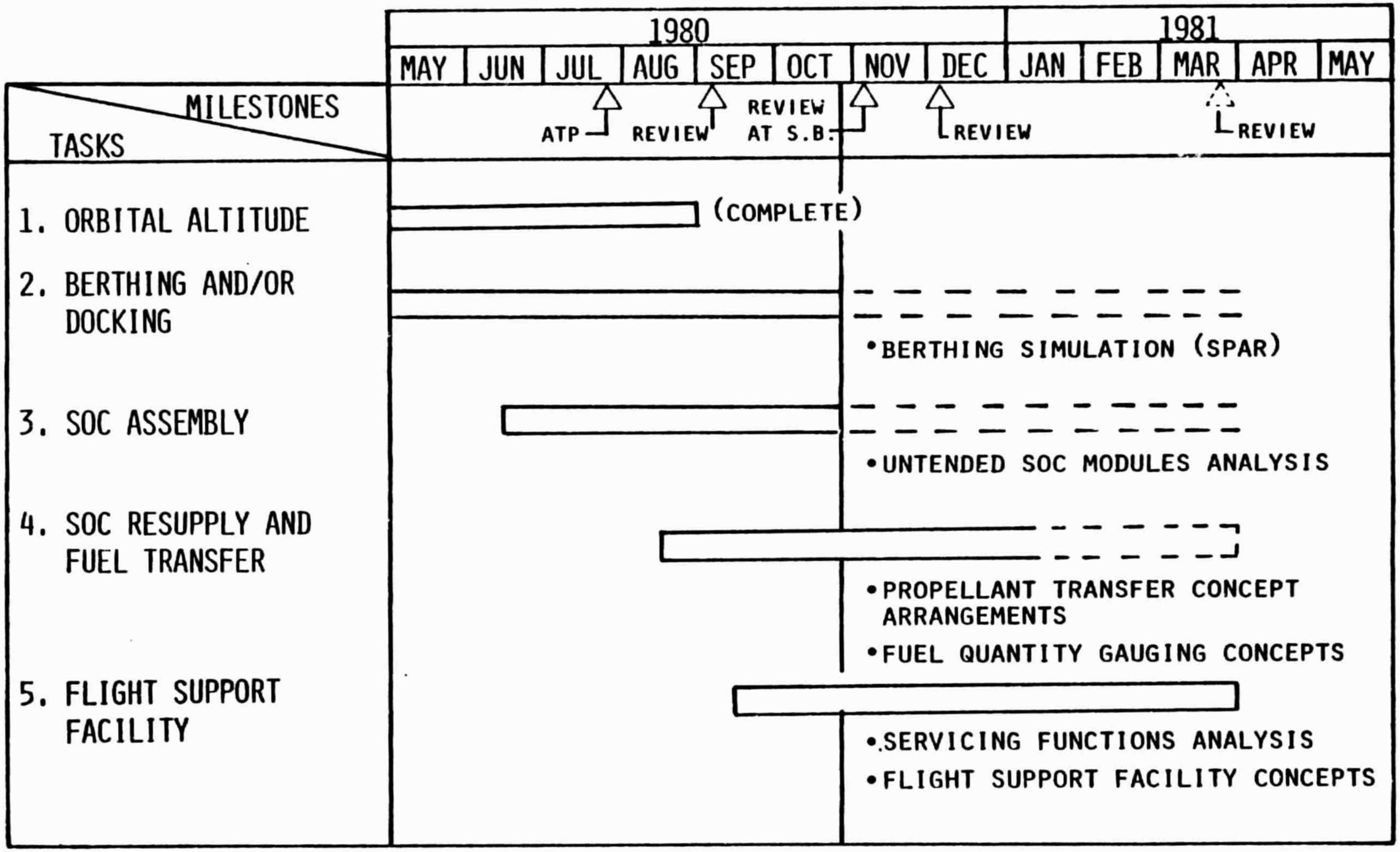


Figure 1. Planned Activity

pellant transfer arrangement concepts, and the Task 5.0 flight support facility efforts.

The mid-term briefing, both at JSC and Headquarters, will also be in preparation during the next reporting period.

C. Action Status

Four action items were assigned to Rockwell at the 30 July 1980 Berthing/Docking Working Group Meeting at JSC.

(1) Cherry picker and MMU stowage concept - completed.

(2) Docking/abort trajectory excursions due to a runaway RCS jet. This item has been completed and is in the process of being documented. The documentation will be included in the next monthly progress report.

(3) Docking ring dynamic motion during impact analysis has been completed and the results are contained in Enclosure (1).

(4) The plume impingement analysis is being deferred pending successful operation of the computer program.

The additional action item assigned during the First Quarterly Review concerning clarification of the evolutionary build-up scenario was completed as noted in the second monthly progress report.

D. Problem Status

No significant problems to report at this time.

SECTION II. TASK PROGRESS (9-19 - 10-24)

Task 1.0 Orbital Altitude

This task is completed.

Task 2.0 Berthing and/or Docking

The action item assigned at the 30 July 1980 Berthing/Docking Working Group Meeting concerning the motion of the docking interface during initial

contact was completed. Enclosure (1) contains the results of this analysis which indicates that a minimum clearance of 5" exists between the orbiter forward fuselage upper TPS and a module being docked. A worst-worst case was assumed that considered the maximum initial contact misalignment and the bottoming-out of the docking mechanism attenuators.

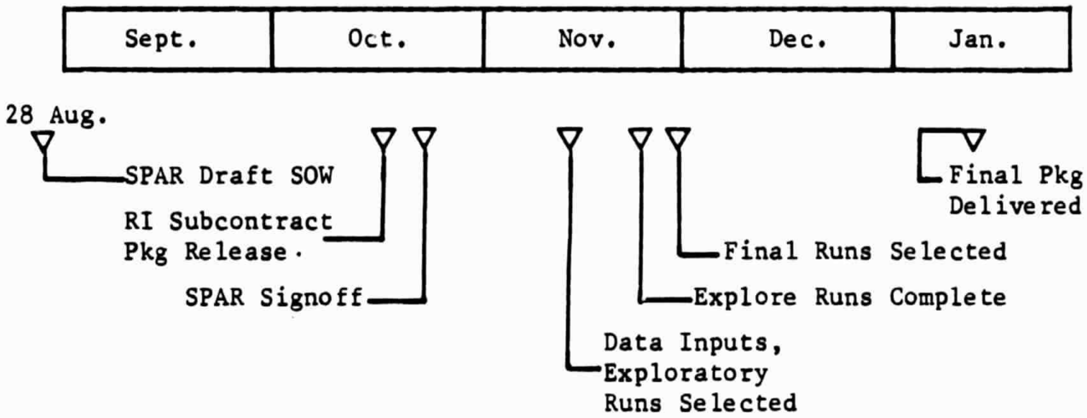
An analysis was also performed to determine if payloads such as large logistics modules/cradles that are envisioned for support of the flight support servicing operations and support of space construction operations can be deployed and transported to their using positions. The concern was that the clearance between the orbiter and the flight support operations would either create a hazardous transport condition or be insufficient to maneuver these payloads to obtain clearance. Re-orienting the orbiter at 90° increments and other angles were investigated to determine if these positions would be more advantageous. The impact to the orbiter would principally be in the inclusion of a rotational capability on the docking module to accomplish these various orientations. Enclosure (2) discusses this analysis and includes charts that illustrate the payload transport paths and the docking module rotational impact. The conclusion, however, was that the nominal location of the orbiter was acceptable even though the transport path is more devious than some of the reoriented orbiter positions, no significant advantage was noted. Sufficient clearance to deploy, maneuver and transport the logistics modules was indicated with the orbiter attached to the SOC in its nominal position.

The subcontract with SPAR is now in the final signoff phase of implementation. The contract package was completed with Rockwell signoff on 23 October 1980 and mailed to SPAR. SPAR acceptance is expected during the week ending 31 October 1980.

The basic approach planned for the simulation analysis is to set up two exploratory runs with initial conditions which are expected to relatively severely tax the RMS system (but within its capabilities). The purpose of the exploratory runs is to determine if arm/joint geometry is more significant than relative motion characteristics in the initial stopping action. Based on the results of these runs, additional cases will be generated to search out critical parameters and their limiting values.

Only a limited number of cases can be run due to the relatively high costs of these complex simulations. However, with these selected cases it is planned to show that the capability exists for handling higher residual rates than predicted for orbiter stationkeeping operations (0.03 fps). In this way, the general feasibility of RMS berthing will be established.

The planned simulation study schedule is as follows:



Task 3.0 SOC Assembly

The SOC assembly lighting analysis is in progress. This task will determine the lighting requirements and lead to the definition of a lighting concept for the SOC assembly operation.

The analysis concerned with the impacts to the SOC modules in their untended position during the SOC buildup has been initiated. This effort is concentrating on the impacts associated with the G&C system, and will be comparing the impacts associated with the nominal SOC buildup sequence and an evolutionary SOC buildup sequence.

Task 4.0 SOC Resupply and Fuel Transfer

Propellant transfer trades are being analyzed that are associated with the transfer lines configuration. This effort is considering the impacts to the orbiter, the docking module, the SOC service modules, and the flight support facility. Line sizes and number of lines, line joint arrangements, and fuel storage facilities are being considered.

An analysis was performed to determine the impacts to the orbiter to accommodate a full SOC crew compliment of eight persons. The analysis assumed that the mid-deck area of the orbiter cabin was the only available area for the accommodation of the passemgers. Enclosure (3) discusses this analysis and illustrates the options that were developed. The selected arrangements are indicated. Two arrangements are considered feasible; (1) with the airlock in the cabin, and (2) without the airlock. Storage facilities were considered to be adequate for the short span of time anticipated for this operation. However, more vigorous investigation is necessary to verify the stowage accommodation and the operational considerations, particularly if the flight time is as long as eight hours.

An analysis was also performed to determine the operational procedure for deploying, transporting, and exchanging logistics modules. The analysis was performed in two parts; (1) considering the SOC logistics module, and (2) considering the logistics modules/cradles anticipated for support of

the flight support and space construction operations. Enclosure (4) and Enclosure (5) discusses these studies. Both studies resulted in the identification of the need for the handling and positioning aid. This device was considered to be the most desirable piece of equipment for holding the modules during the exchange operation. The studies also recommended that the orbiter RMS be the transporting device for the SOC logistics module while the RCM of the SOC perform the transportation function for the flight support and space construction logistics modules/cradles.

Task 5.0 Flight Support Facility

Various flight support facility configuration options are presently being generated in order to define a baseline arrangement. The selected arrangement will be modified as the flight support servicing functions are analyzed and integrated into the concept.

The flight support servicing functions are being identified utilizing the MOTV model as defined by Rockwell, Boeing, and JSC and contained in the second monthly progress report.

SECTION III. TASKS PLANS

Task 1.0 Orbital Altitude

Completed.

Task 2.0 Berthing and/or Docking

The effort of this task will be the implementation of the SPAR activity to determine the capability/feasibility of utilizing the orbiter RMS to perform an orbiter to SOC berthing operation.

Task 3.0 SOC Assembly

The principal effort of this task will be the untended SOC module analysis and the impacts to the G&C system. This effort has just started and will continue thru the next reporting period.

The analysis of the lighting requirements and concepts for SOC assembly will also be continuing during the next reporting period.

Task 4.0 SOC Resupply and Fuel Transfer

Effort will continue toward the final definition of an OTV propellant (cryo) transfer concept that will include the transfer line routing and distribution concepts. Propellant gauging techniques analysis will also be continuing during this next reporting period.

Task 5.0 Flight Support Facility

The development of flight support facility options will continue into the next reporting period. Servicing functional analysis will be started with the identification of the servicing functions which are presently in progress.

SECTION IV. EXPENDITURES

Planned and actual direct labor hours and dollars expenditures are presented in Figures 2 and 3. The figures indicate that the actual expenditures in both dollars and hours have essentially met the planned expenditures during this period.

Figure 2. SPACE OPERATIONS CENTER - SHUTTLE INTERACTION

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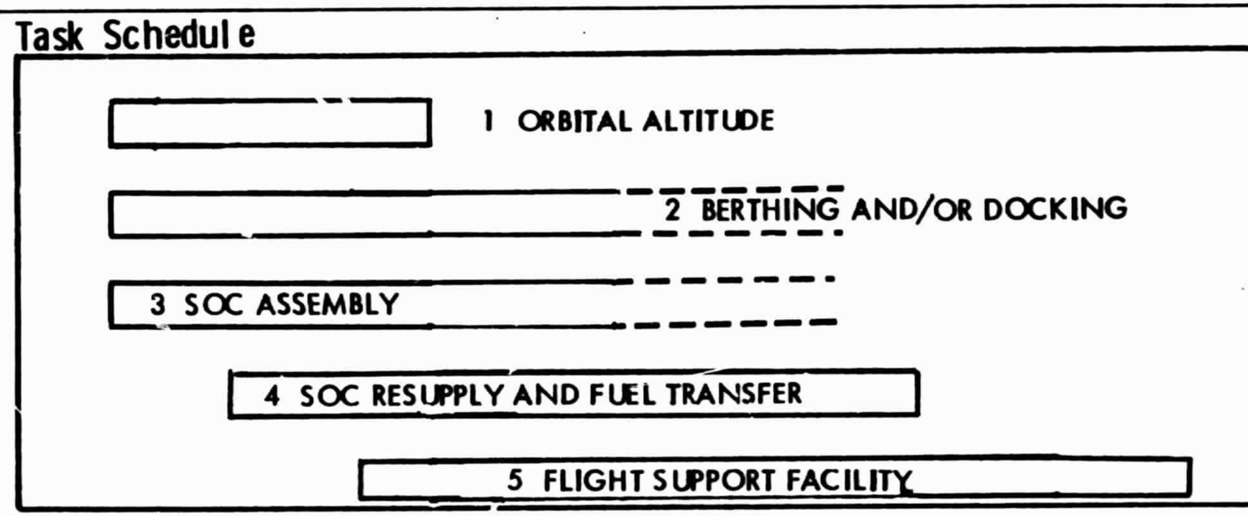

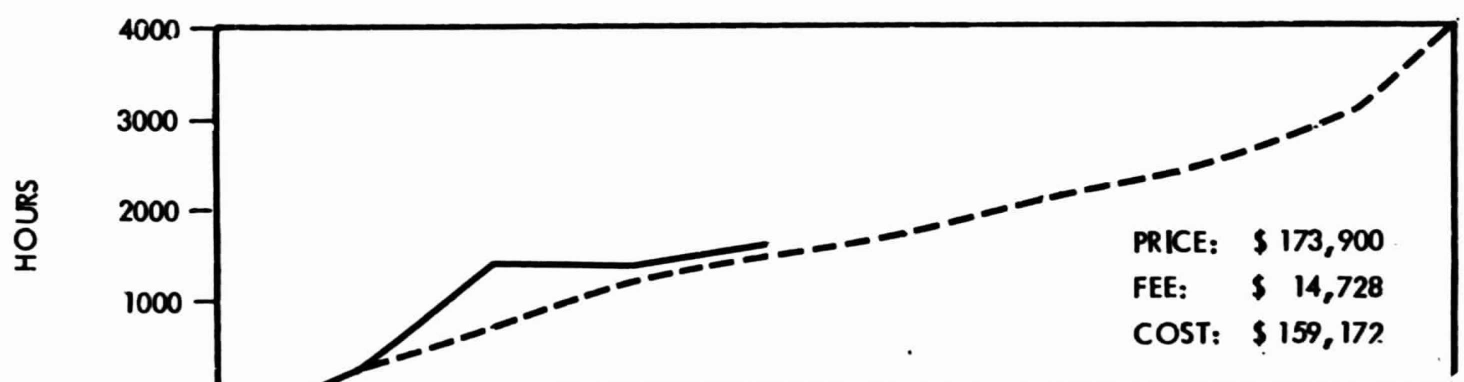

	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR
CUM PLAN	236	754	1200	1518	1752	2174	2432	2948	4102
CUM ACTUAL	258	1472	1405	*1622					
VARIANCE	(22)	(718)	(205)	*(104)					

* Estimated Actuals

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Figure 3. SPACE OPERATIONS CENTER - SHUTTLE INTERACTION

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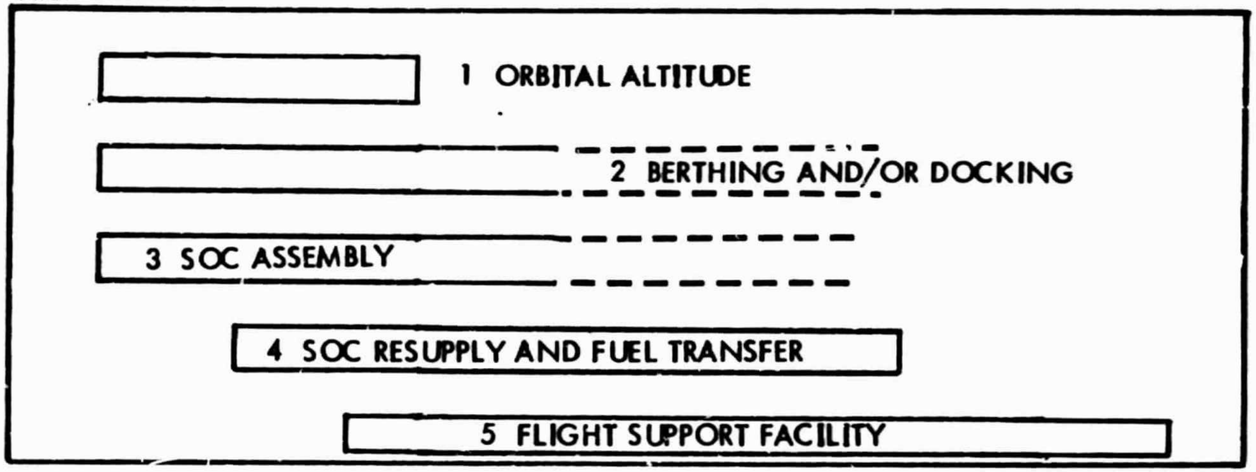
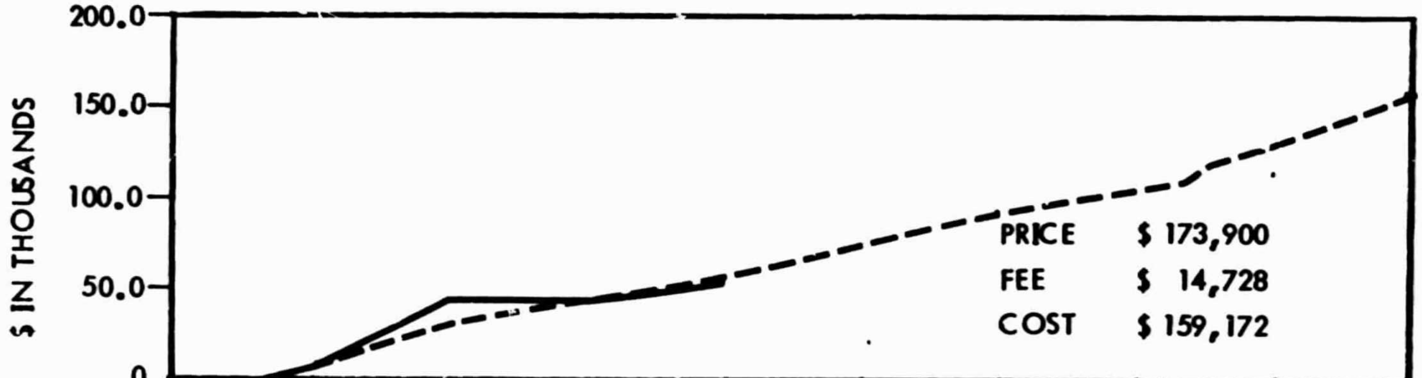
Task Schedule





	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR
CUM PLAN	7.7	28.1	43.5	57.9	67.8	83.4	94.8	115.5	159.2
CUM ACTUAL	8.2	45.1	44.4	*52.3					
VARIANCE	(.5)	(17.0)	.9	*5.6					

*Estimated Actuals

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ENCLOSURE (1)

ORBITER TO MODULE DOCKING

This task was performed in order to respond to an action item that was generated at the 30 July 1980 Berthing/Docking Working Group Meeting at JSC. This investigation was to verify that the docking module interface at orbiter Zo 515 and utilizing an attenuation stroke of 8" would always provide clearance between the orbiter and the mating element.

A 6° out of alignment was used as a maximum mismatch between the docking module and the mating element - the SOC service module in this investigation. The worst attitude deemed possible is with the modules port bottomed out on the forward petal of the docking ring, deflecting same to the maximum angle of 7°. With the 6° misalignment added to this, the module is now pitching towards the cabin roof at an angle of 13°. At this position there is a clearance between the maximum diameter of the module and the TPS tiles of 5".

This condition suggests that the attenuators immediately "bottomed out" and do not impose any restoring moments. The investigation also assumed that the orbiter was a fixed element which did not rotate which might also relieve the impact force. A dynamic analysis of this condition that considers these elements is necessary to provide a final answer to the question. However, this worst, worst case simplistic investigation indicates that the docking module interface location is acceptable and will not permit the mating element to contact the orbiter's TPS during the docking maneuver.

Drawing Number 42690-010 illustrates the docking port and approach sequence.

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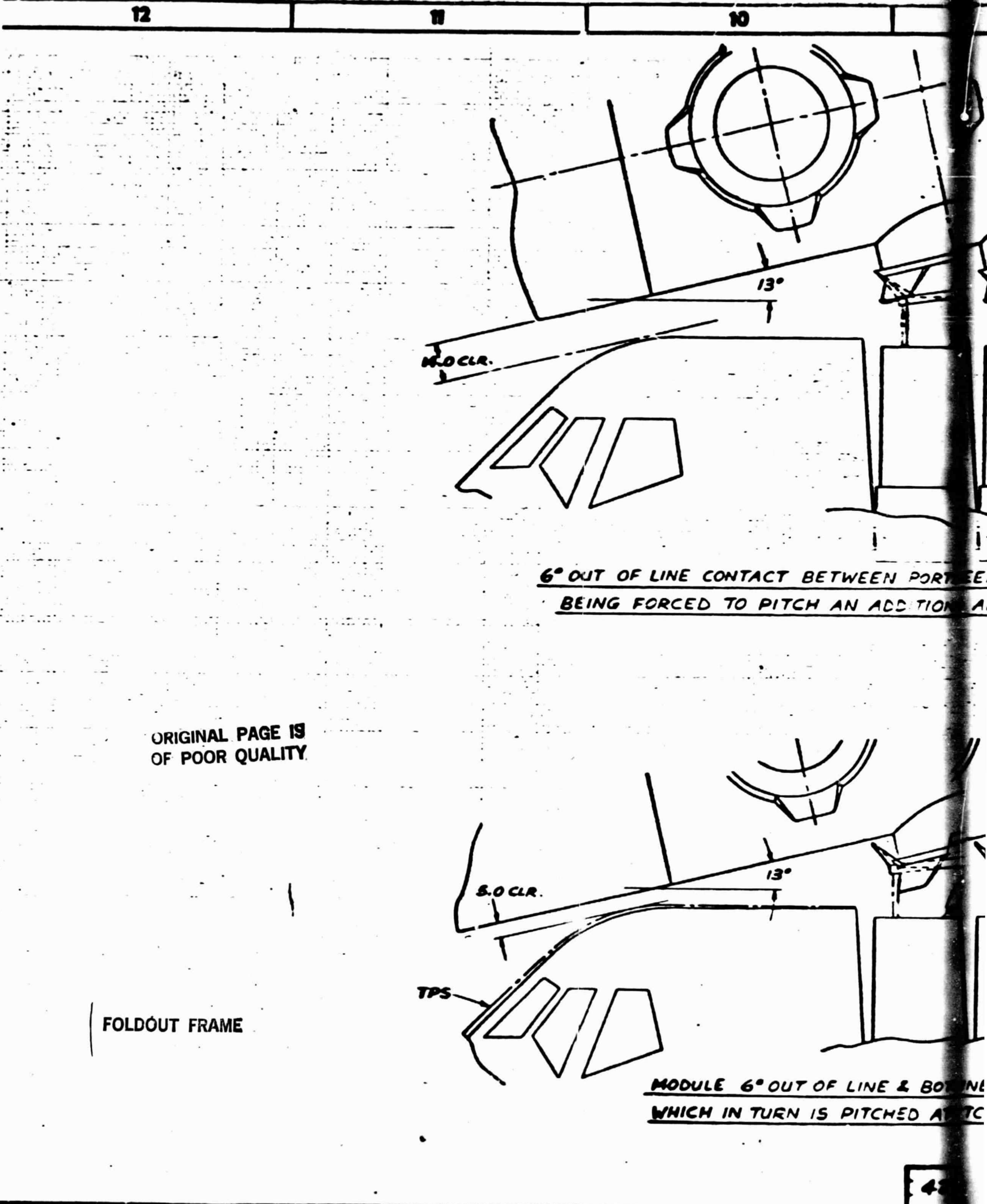

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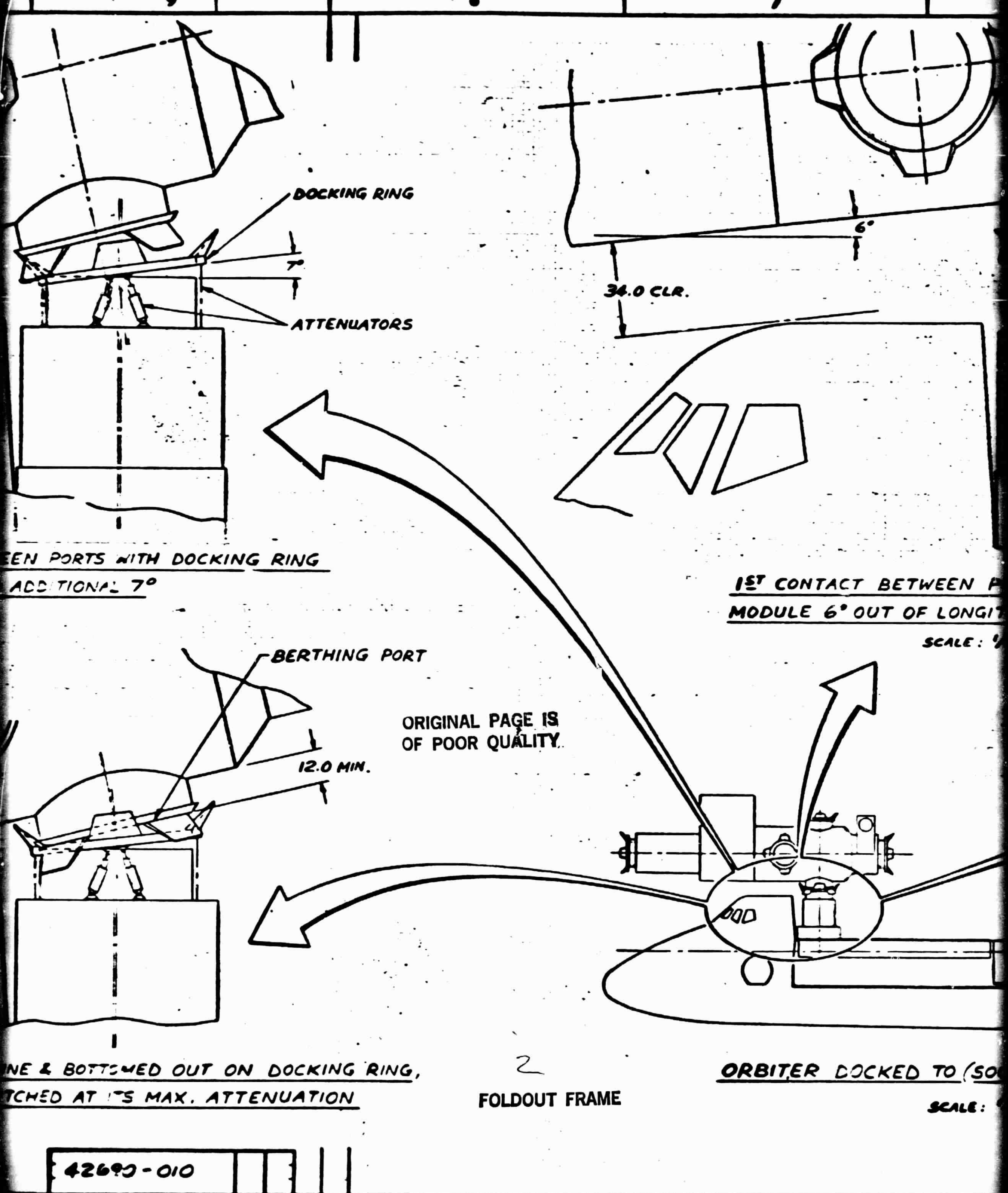

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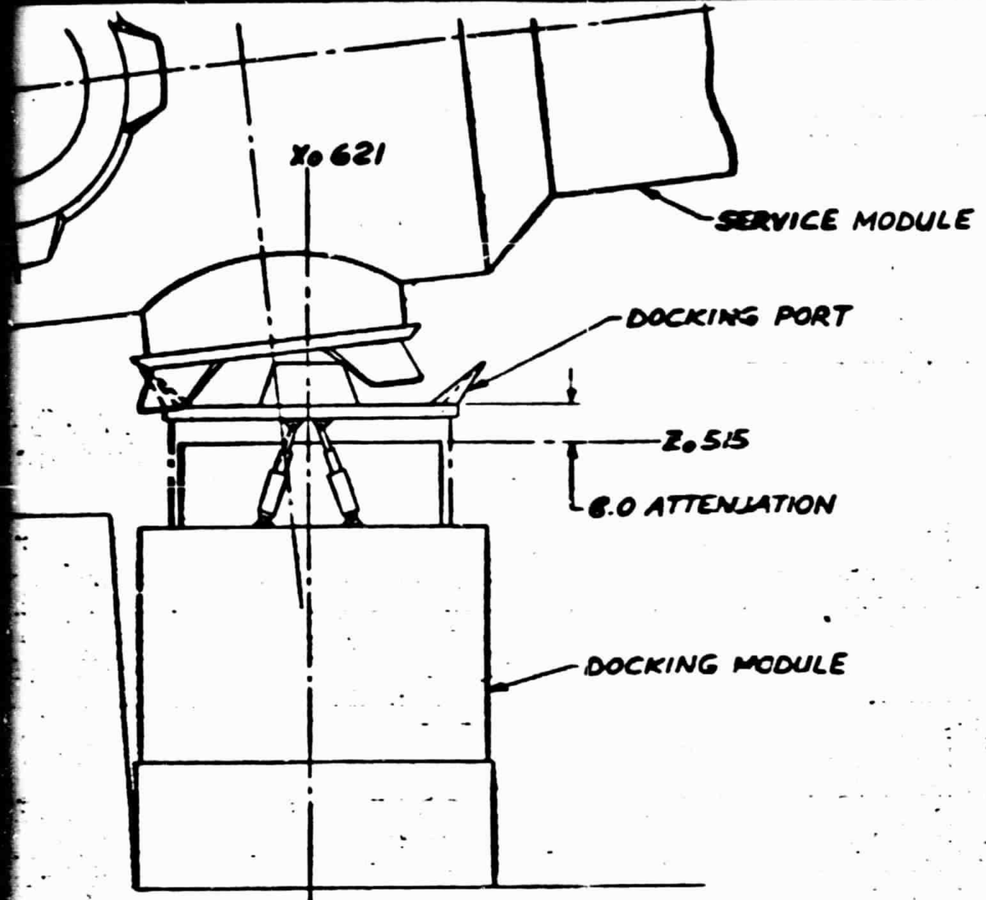
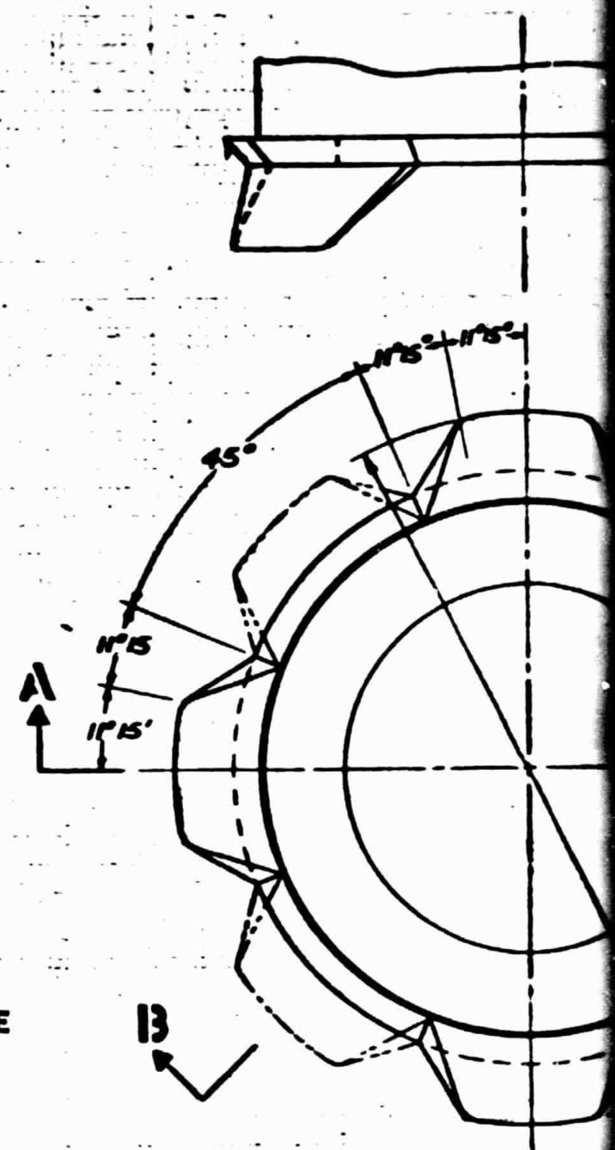


WEEN PORTS (NO ATTENUATION)
F LONGITUDINAL ALIGNMENT
SCALE: 1/20



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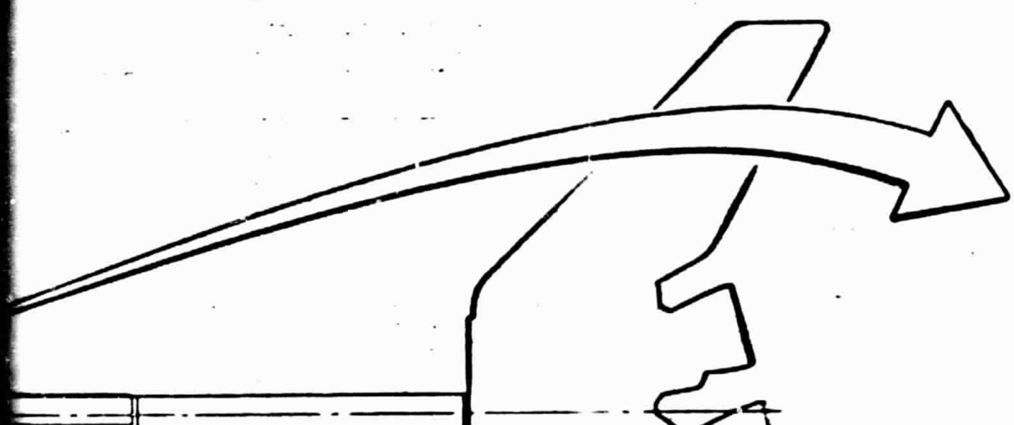
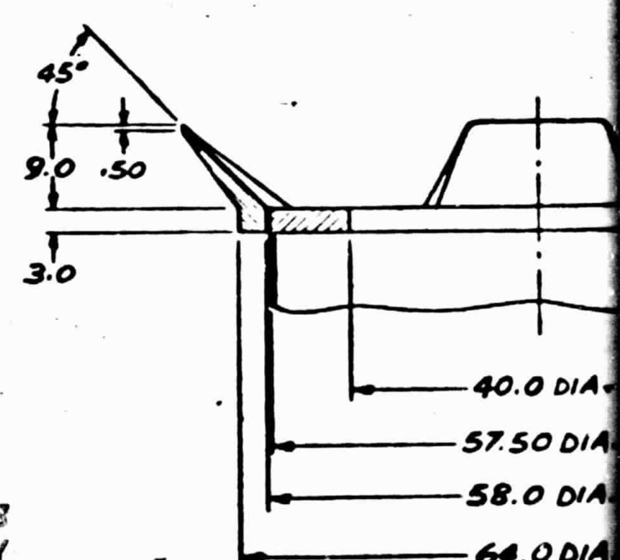
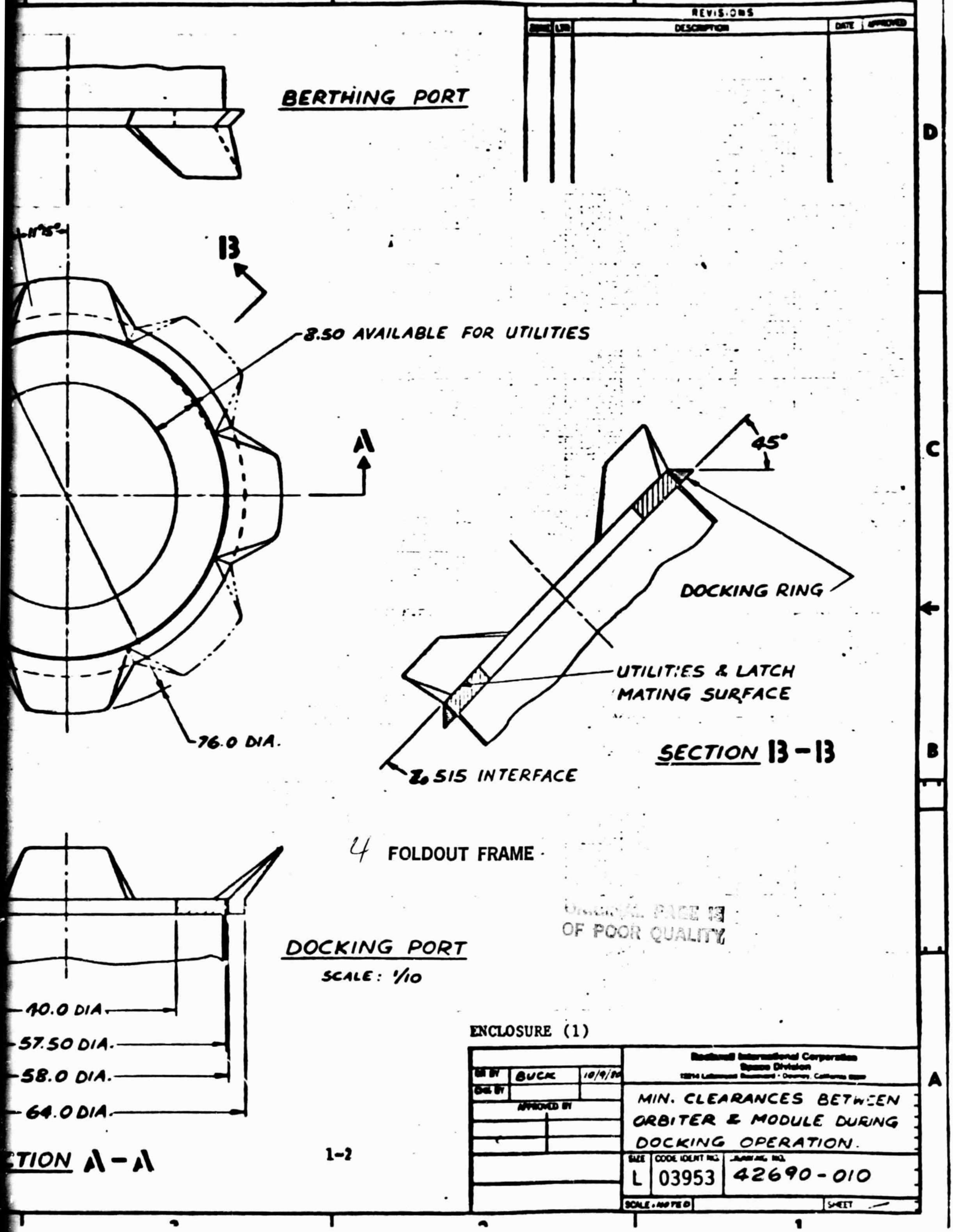


TO (SOC) SERVICE MODULE
SCALE: 1/100



SECTION A



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ENCLOSURE (1)

ENCLOSURE (2)

SOC/ORBITER ORIENTATION

The nominal orientation of the orbiter to the SOC, as illustrated in the enclosed briefing material, requires that the extraction and transport of cargo from the orbiter to its using position follow a somewhat devious path. This path is necessary in order to clear the flight support operations area and to clear the RCS support boom and the solar array support boom. Can this devious path be eliminated by re-positioning or re-orienting the orbiter on the SOC? What are the impacts to the SOC, to the orbiter, and to the docking module? Is additional equipment indicated? These questions were answered by investigating various orbiter positions in relationship to the SOC and also by re-orienting the orbiter at the 90° increments and at 30° and 45° increments. Logistics type operations were synthesized in order to evaluate the various positions and their impacts.

The considerations that were addressed in order to evaluate the various operations are indicated in the enclosure. A flight support logistics cradle positioned, as shown in the enclosure, was one of the logistics operations assumed. This orientation requires the extraction of the cradle from the orbiter cargo bay and re-orienting the cradle by rotating it 90° to permit the berthing of the cradle to the SOC. However, by orienting the orbiter so that it is docked to the SOC in the position that is parallel to the flight support cradle position on the SOC permits a simple transfer of the cradle from the cargo bay to the SOC without the additional 90° rotation of the cradle. This arrangement, however, affects the docking utilities interface connections. In order to maintain the nominal interface connections across the orbiter/SOC interface, a rotational capability on the docking module appears to be the most desirable solution. This rotational concept is illustrated in the enclosure. The delivery of the SOC logistics module also has the same operational constraints as the flight support cradle delivery.

The transport of a space construction cargo cradle to the vicinity of the space construction operations was also analyzed. The extraction of such a cargo cradle from the cargo bay and the transport to the stowage position, illustrated in the enclosure, requires that these operations stay within the transport clearance envelope as previously shown. The principal concern is the clearance with the flight support facility and the clearance of the solar array boom and RCS support boom. By repositioning the orbiter so that the cargo bay is in line with the transport path described by the solar array and RCS boom clearance envelope eliminates the flight support clearance concern. This repositioning operation can be achieved by use of a device such as the holding and positioning aid illustrated in the enclosure.

A 45° rotation of the orbiter about the principal SOC/orbiter interface docking position also will locate the orbiter cargo bay in a more advantageous position for the transport of elements such as the construction cargo cradle. This concept, however, requires the rotational capability to be available within the orbiter's docking module.

Both the parallel repositioning and the rotational repositioning concepts place the orbiter in line with one of the SOC RCS engine pods, thus, subjecting the orbiter to the plume impingement. These concepts also place the orbiter within the heat rejection path of SOC radiator panels. Orbiter heat rejection is also impacted.

Final analysis of this investigation was that the cargo can be removed from the orbiter cargo bay and transported to its using position on the SOC with the orbiter docked to the SOC in the nominal position. Sufficient clearance is available between the orbiter and the flight support facility and between the SOC and the RCS and solar booms to perform this operation even though the transport path is somewhat devious. The additional rotational requirements imposed on the docking module, or the implementation of a handling and positioning aid doesn't appear to be justified to achieve only less time or complexity in performing these operations. Consequently, no special orbiter orientation to accommodate these operations is recommended.

SOC/ORBITER OPERATIONS & ORIENTATION CONSIDERATIONS

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A. OPERATIONS:

- DELIVERY OF LOGISTICS MODULE - TASK 4 (1)
- DELIVERY OF LOGISTICS CONST. & FLIGHT SUPPORT SERVICING CRADLES
- REFUELING & SERVICING OF ORBIT TRANSFER VEHICLE - TASK 4 (2)(3)

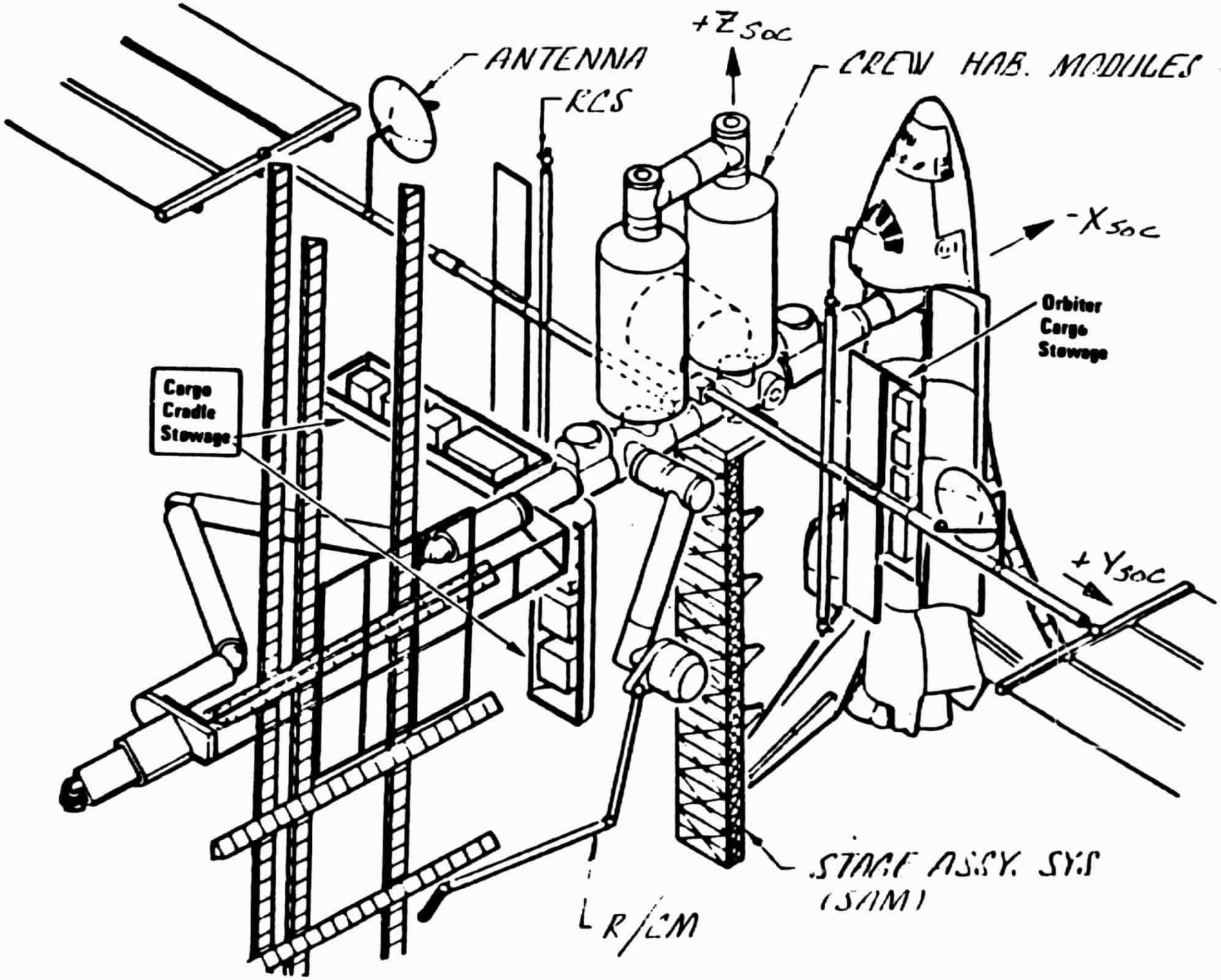
B. ORIENTATION CONSIDERATIONS:

- DOCKING AT 90° INCREMENTS
- ROTATIONAL CAPABILITY OF DOCKING MODULE
- UTILIZATION OF HANDLING & POSITIONING AID
- UTILIZATION OF ON-BOARD SHUTTLE RMS
- USE OF SOC RMS CONTROL MODULE (RCM) FOR REMOVING SYSTEM MODULES FROM SHUTTLE

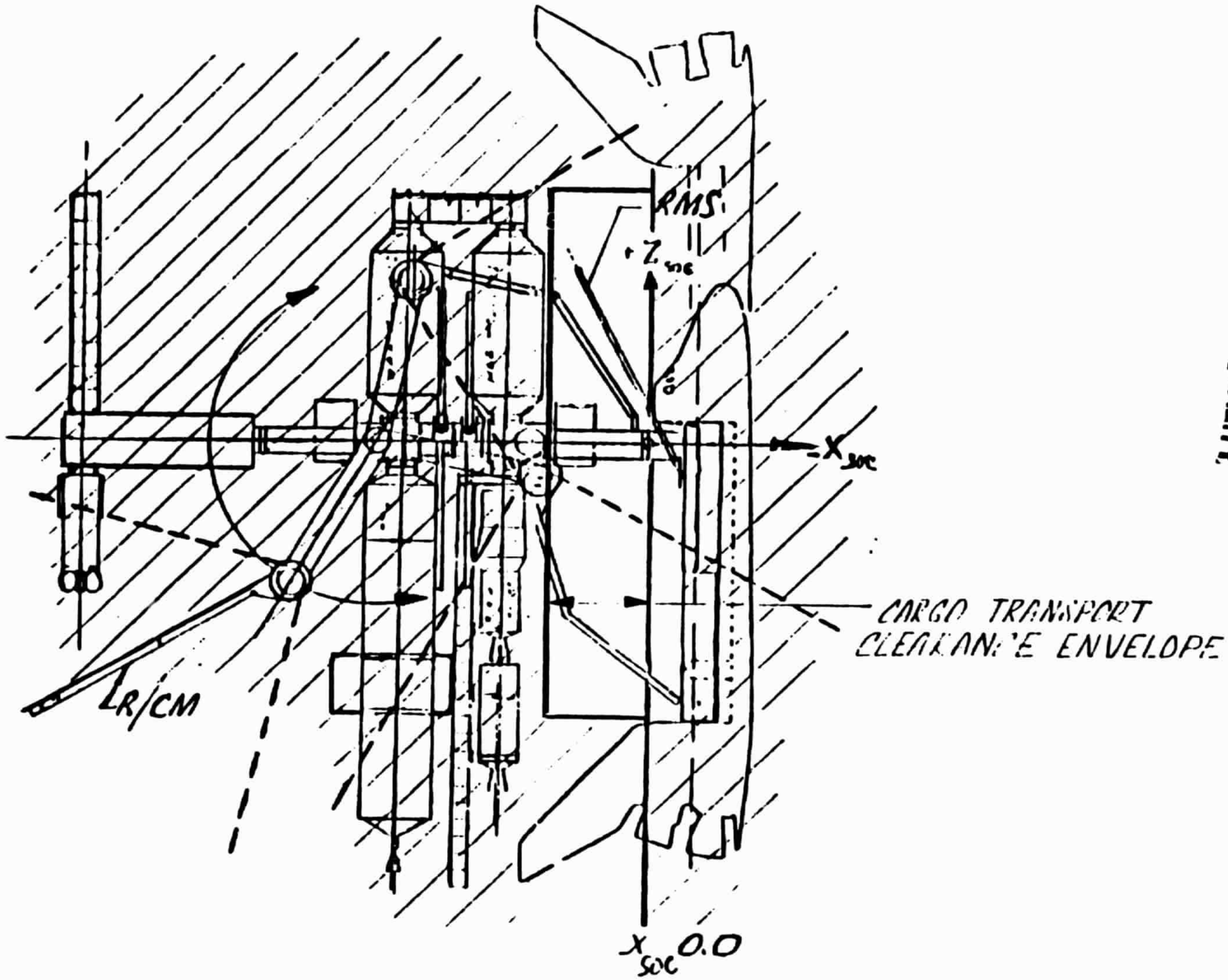
C. OPERATIONAL INPACTS WITH SOC CONFIG.

- OPERATIONAL CLEARANCES WITH RCS MODULES & SUPPORT BOOMS
- INPACT OF SYSTEMS & OPERATIONS BLOCKING RADIATION PATH OF RADIATORS ON BOTH SOC & ORBITER
- PLUME EFFECTS OF SOC RCS
- ANTENNA FIELD-OF-VIEW
- LIGHTING

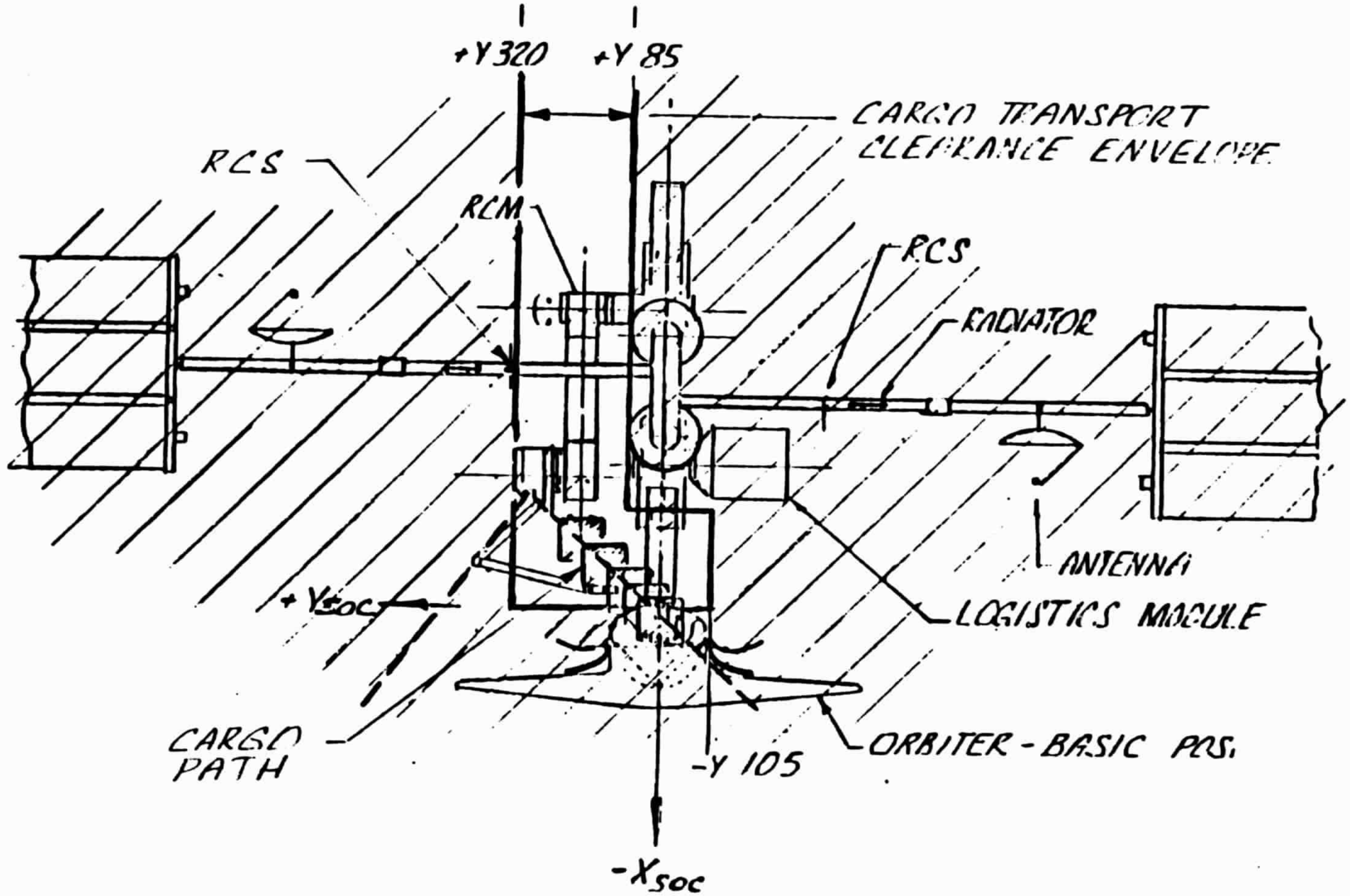
SOC/ORBITER CONFIGURATION



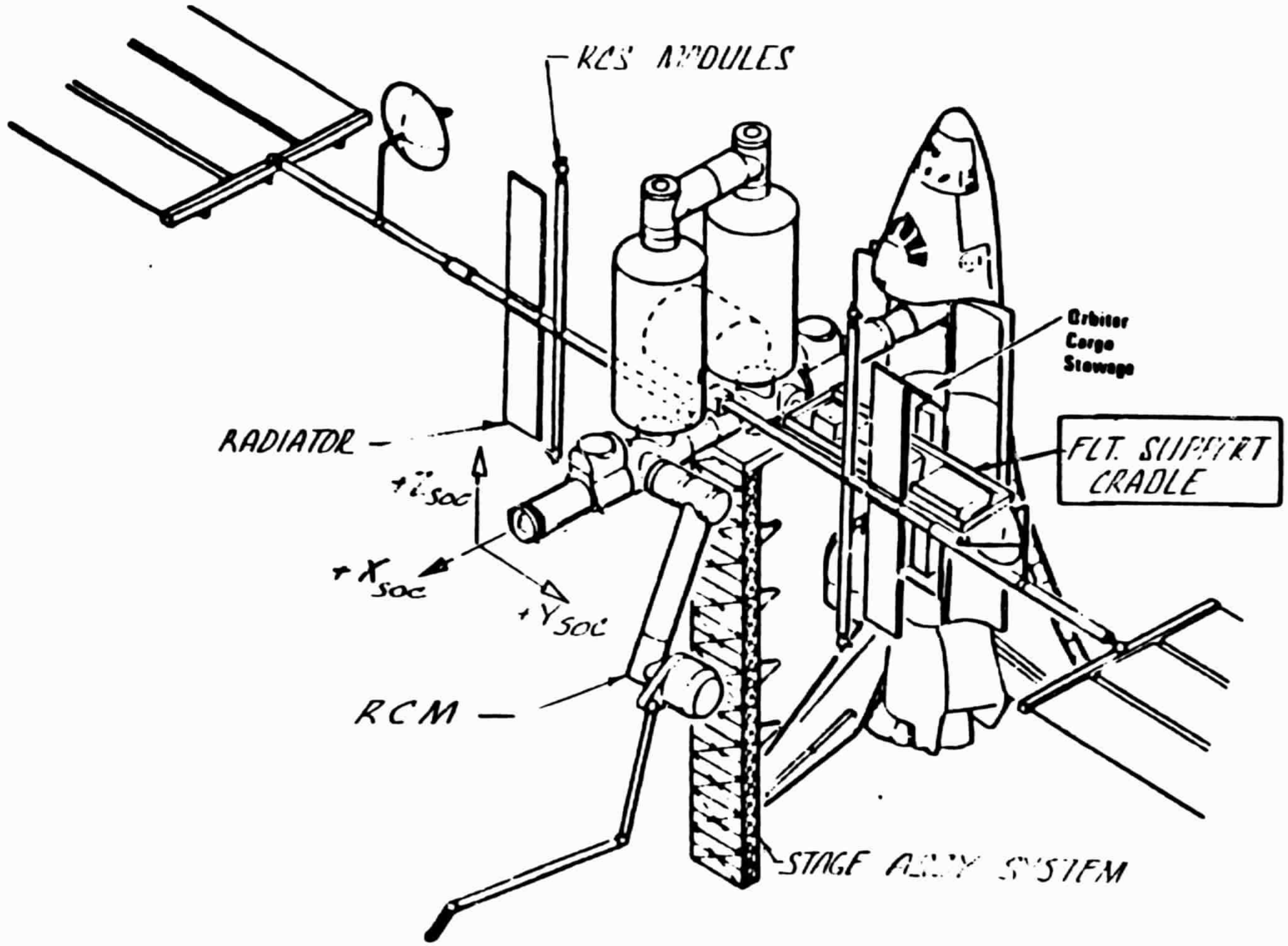
SOC/ORBITER CONFIG. – OPERATIONAL CLEARANCE



SOC/ORBITER CONFIG. - OPERATIONAL CLEARANCE



SOC - LOGISTICS CRADLE INSTALLATION



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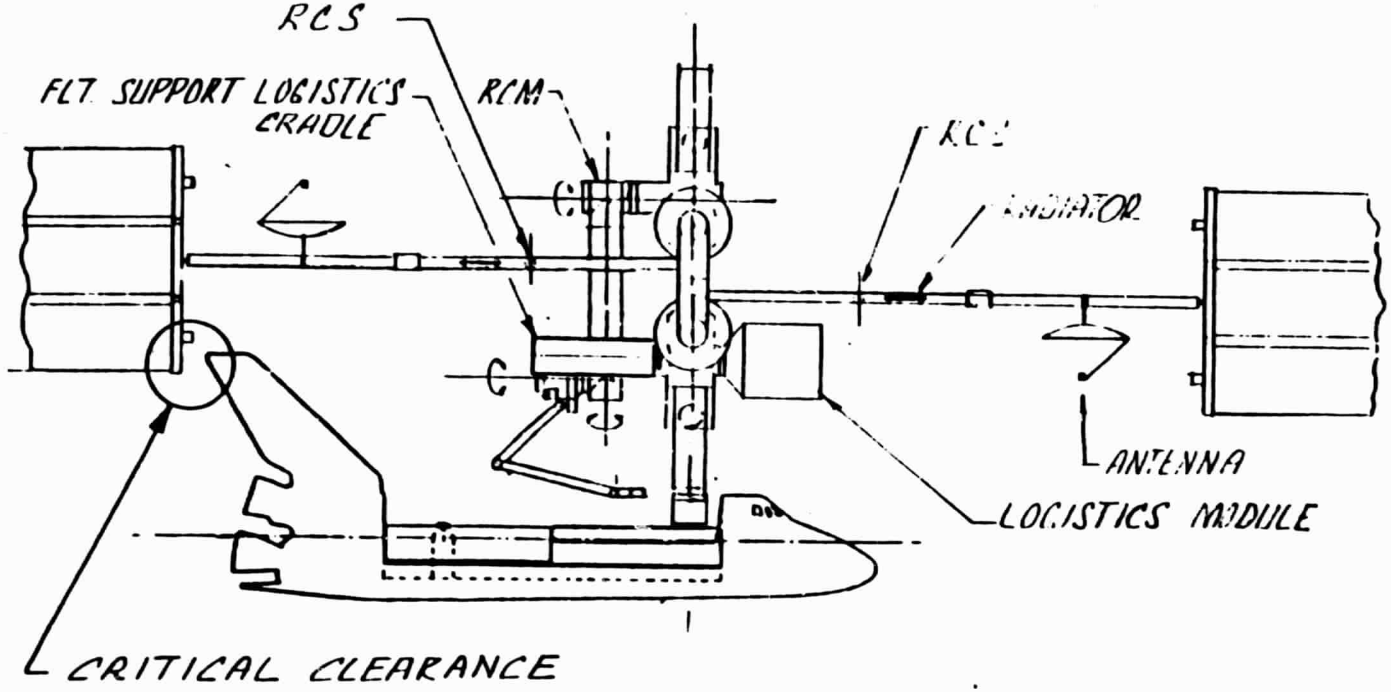
SOC/ORBITER ORIENTATION CONCEPT – 90° ROTATION



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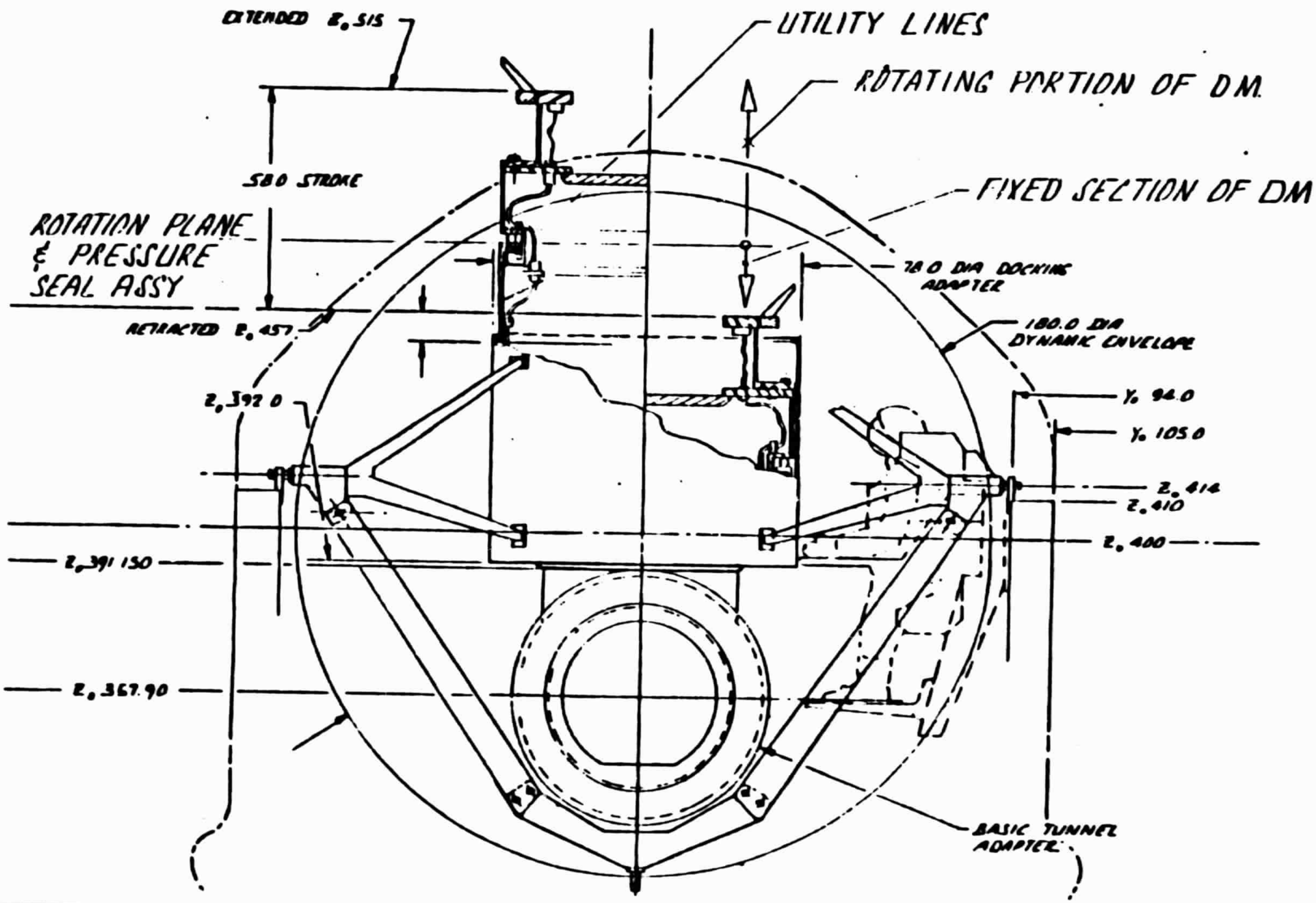
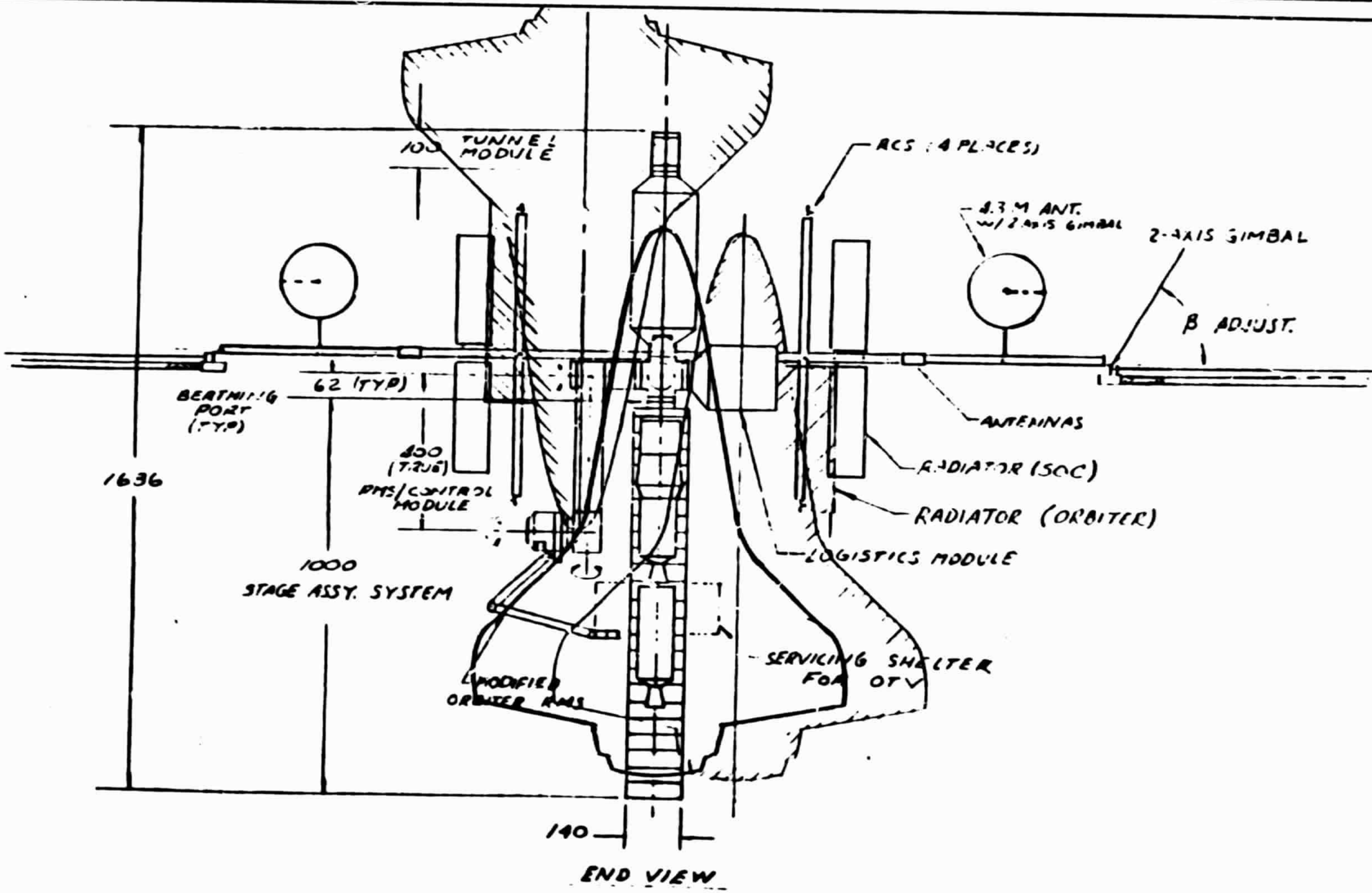
DOCKING MODULE ~ ROTATIONAL CONCEPT



SDC/ORBITER ORIENTATION CONCEPT - REPOSITION



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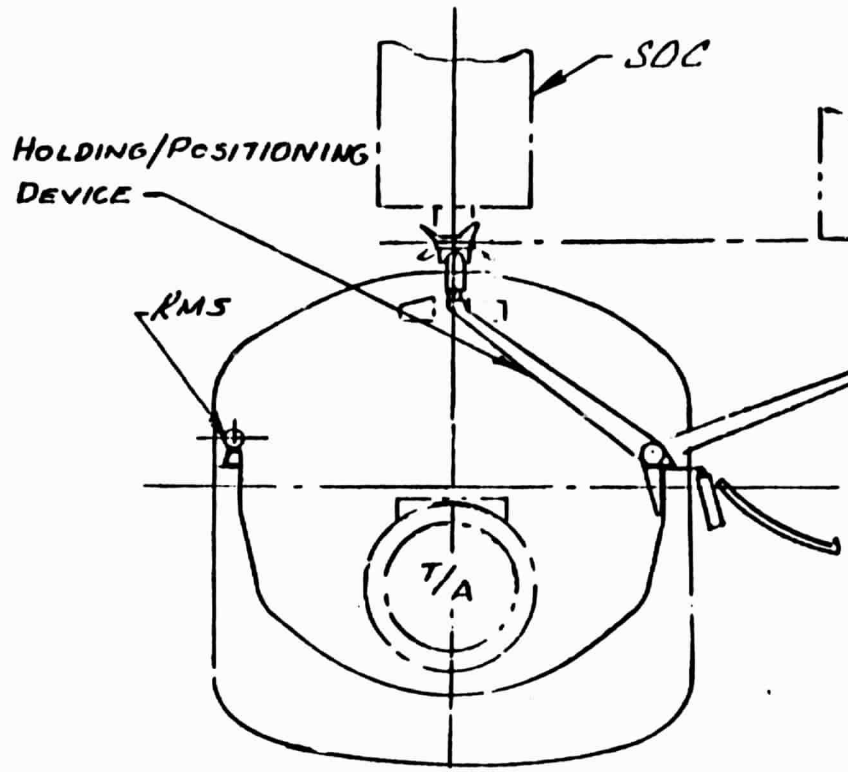
HOLDING & POSITIONING AID FOR ORBITER REPOSITIONING



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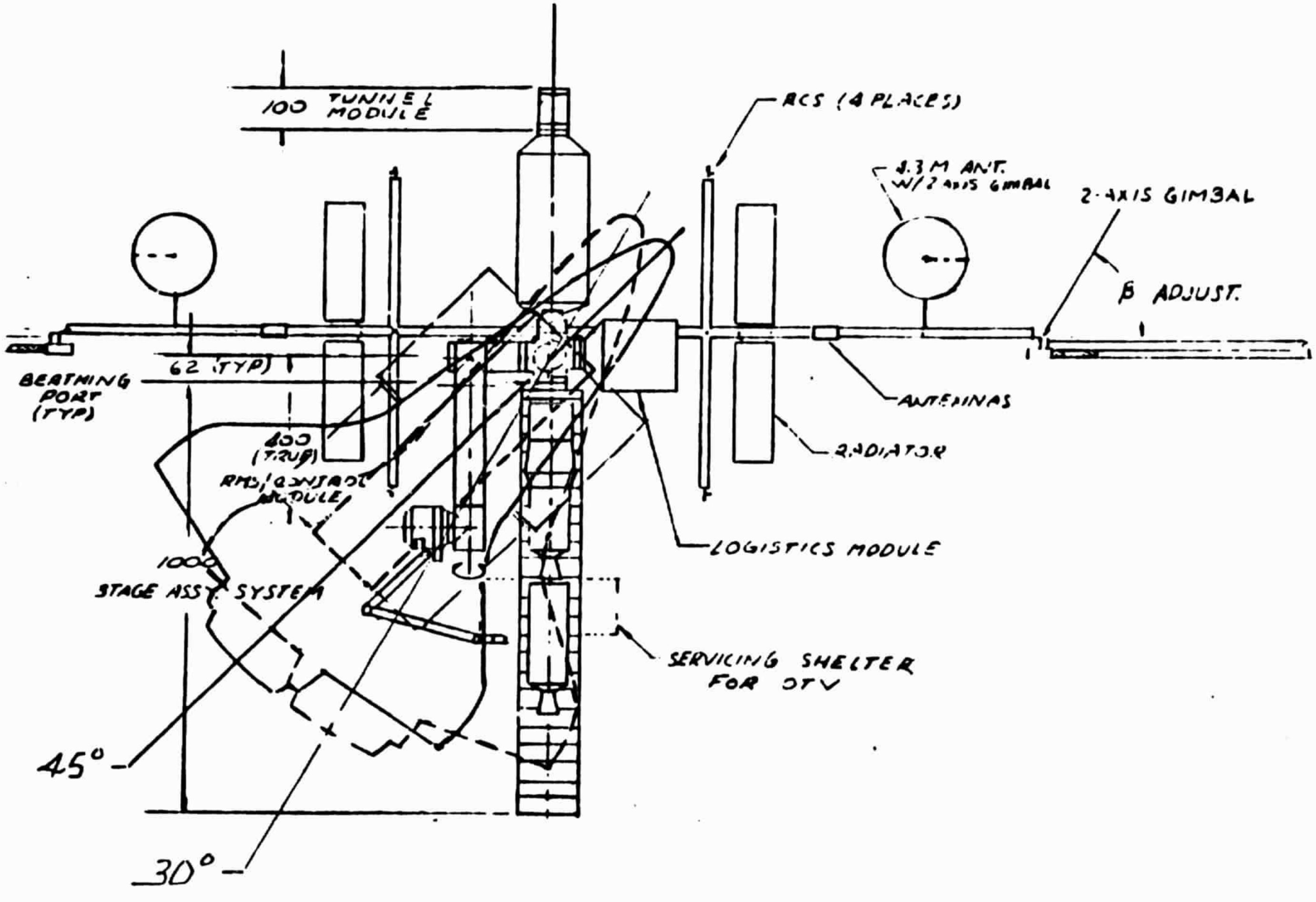
SOC/ORBITER ORIENTATION CONCEPT - 45° ROTATION



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CONCLUSIONS

- LOGISTICS CRADLE CAN BE EXTRACTED FROM THE ORBITER WHEN ORBITER IS IN THE NOMINAL ORIENTATION POSITION. (SENSITIVE OPERATION TO CLEAR SAM & RCS BOOMS)
- 90° ORIENTATION PLACES ORBITER IN-LINE WITH SOLAR ARRAY BOOM. (RADIATOR, ANTENNA BLOCKAGE; PLUME IMPINGMENT)
- 45° ORIENTATION PLACES ORBITER IN POSITION FOR DIRECT EXTRACTION OF CRADLES. (REORIENT CRADLES FOR TRANSPORT SOC RADIATOR PANEL BLOCKAGE, RCS PLUME IMPINGEMENT)
- TRANSLATED ORBITER VIA HAPA PLACES ORBITER IN POSITION FOR DIRECT EXTRACTION OF CRADLES. ORBITER ORIENTED 180° FROM NOMINAL POSITION. (PLACEMENT PROCEDURE OF ORBITER ON SOC VIA HAPA TBD)

RECOMMENDATION

RETAIN NOMINAL ORBITER/SOC DOCKING ARRANGEMENT

ENCLOSURE (3)

ORBITER MID DECK SEATING ARRANGEMENT FOR SOC
CREW DELIVERY/EXCHANGE

The orbiter crew station and the passenger accommodations are comprised of working, living and equipment stowage facilities. Charts in the enclosure illustrate the basic orbiter configurations within both the crew flight deck and the mid-deck compartment. This study did not consider utilizing any of the flight deck for the purpose of passenger seating so that all concepts considered to meet the requirements were conducted using only the mid-deck level. This deck contains storage facilities, inflight provisions, and accommodations for four crew sleep stations. Stowage provisions include modular racks Li canisters, waste management, personal hygene station, work/dining table, seats and mobility aids. Access to and from the orbiter is through a side hatch into the mid-deck area. Access between the mid-deck and the flight deck is accomplished by a ladder and through a hatch opening in the floor. Access from the mid-deck to the payload bay is via an airlock which is shown within the mid-deck envelope. This airlock, however, can be located either in the mid-deck or in the payload bay.

With the basic conditions as stated in the above mentioned text, four concepts were configured using the mid-deck level. Two concepts, -01 and -03, show a seating arrangement that uses the basic orbiter seating with the addition of two seats located near the galley module. This arrangement requires that the modular lockers in the forward portion of the mid-deck be removed in total or in part to provide both seating and mobility access to/from the egress/ingress hatch. Storage for crew personal effects and emergency support equipment can be accommodated in the shaded area as shown on the enclosure charts for each concept.

Concepts -02 and -04 reflect configurations where the airlock is to be located in the payload bay. These two concepts again utilize the basic orbiter seating with the relocation of the additional seating so that clear access and mobility paths to the primary hatch are provided. The two seats located in the floor, formally occupied by the airlock, were positioned to provide space for utilities to operate the hatch cover of the airlock. These concepts also retain the basic orbiter stowage compartments as shown on the enclosures. Final analysis of this study is that provisions for a SOC crew delivery and transfer can be accomplished with minor modifications to the orbiter mid-deck.

Additional analysis is required to determine if there are any impacts to the ECLSS system, and to verify the stowage requirements and implications of the emergency oxygen system.

SOC/ORBITER CREW SEATING CONSIDERATIONS

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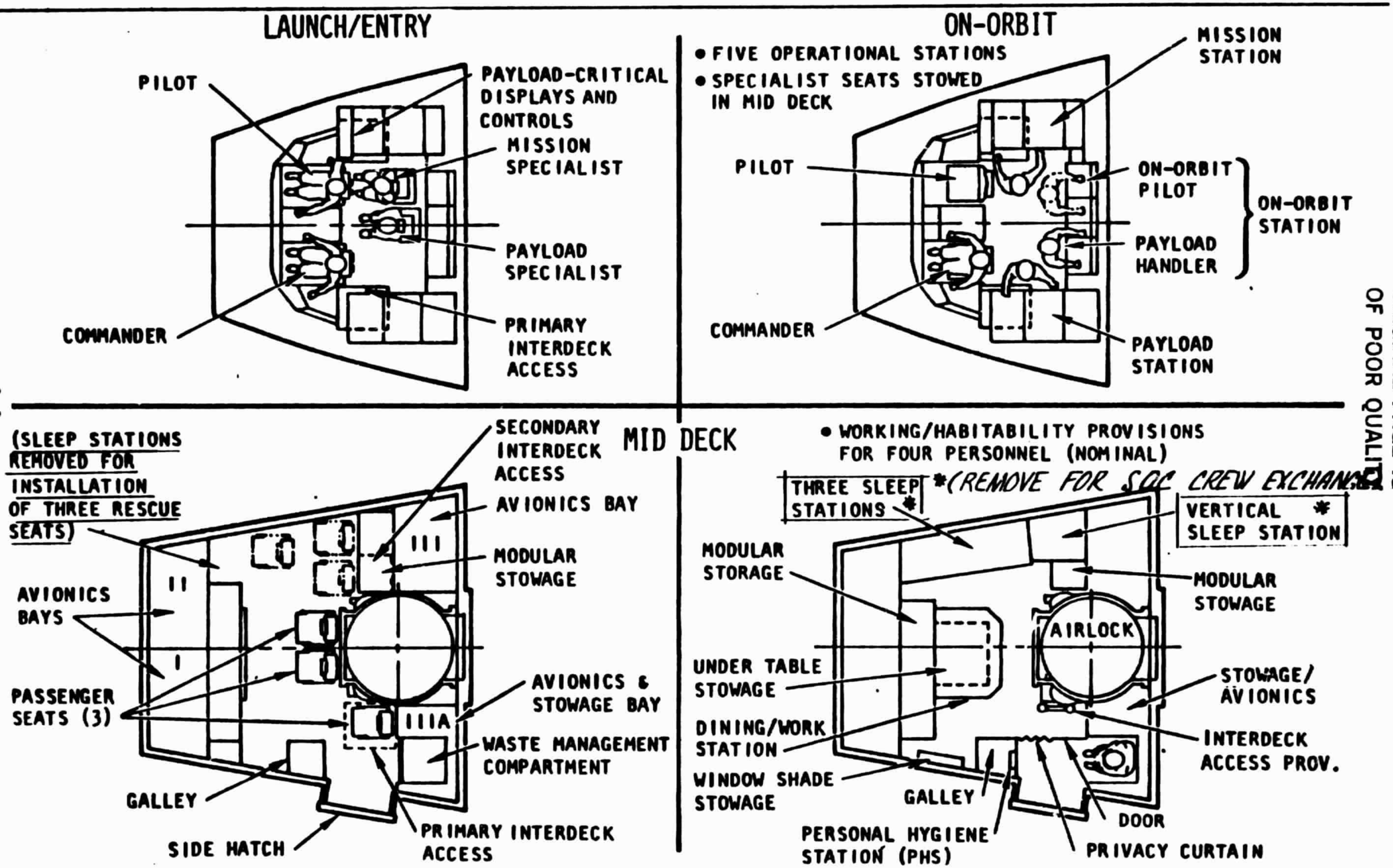
OBJECTIVE:

WITH A SOC CREW CONSISTING OF EIGHT PEOPLE, CONFIGURE A SEATING ARRANGEMENT ON THE ORBITER MID DECK, THAT CAN ACCOMMODATE THIS GROUP FOR THE PURPOSE OF EFFECTING A COMPLETE SOC CREW EXCHANGE

REQUIREMENTS:

- CONFIGURE ORBITER MID DECK TO PROVIDE SEATING FOR A MAXIMUM OF 8 CREW MEMBERS
- SEATING ARRANGEMENT POSITIONED TO PROVIDE A CLEAR EMERGENCY PATH TO THE PRIMARY INGRESS/EGRESS HATCH OPENING
- PROVIDE ACCOMMODATIONS FOR EMERGENCY CREW SUPPORT PROVISIONS AND CREWS PERSONAL EFFECTS WITHIN AVAILABLE STOWAGE AREAS

ORBITER FLIGHT DECK/MID-DECK BASIC CREW CABIN ARRANGEMENT



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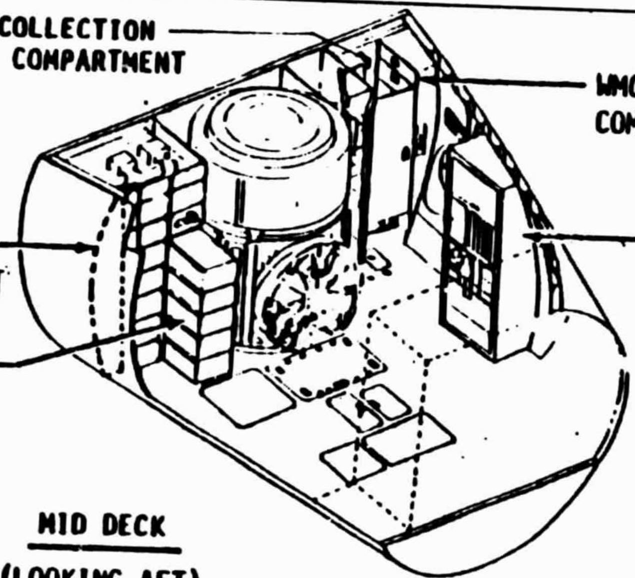
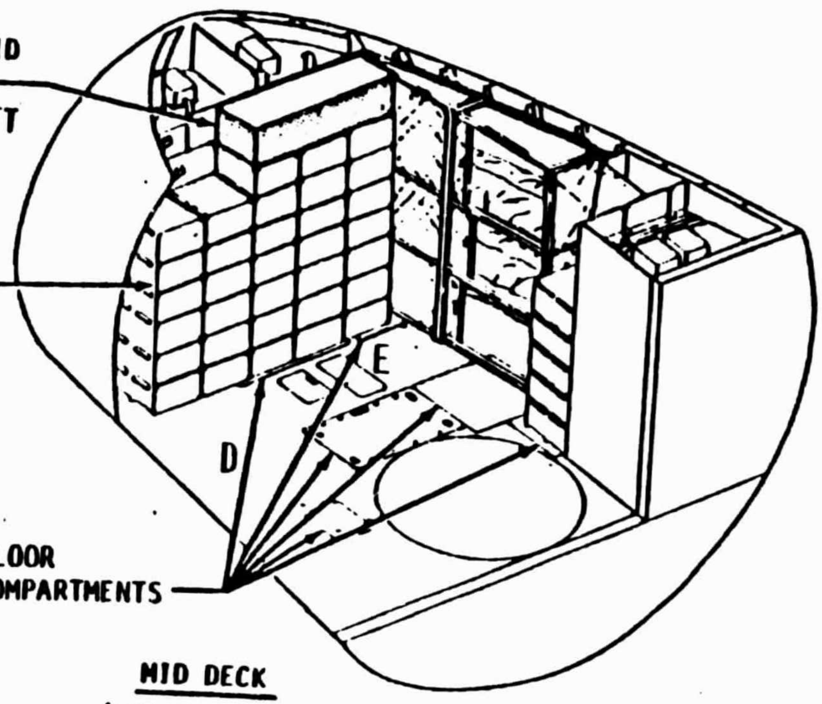
BASIC OPERATIONAL MID-DECK LAUNCH/ENTRY CONFIGURATION

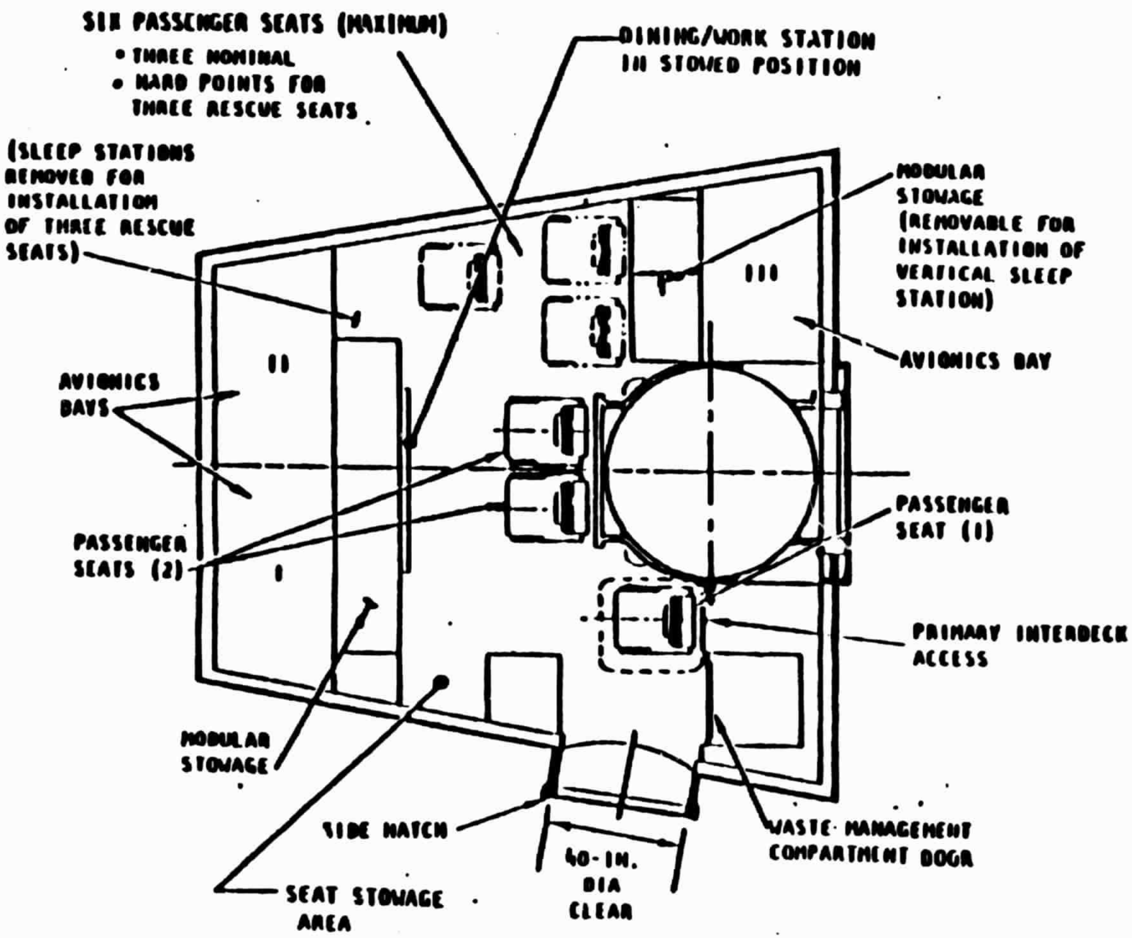


MID DECK
(LOOKING AFT)

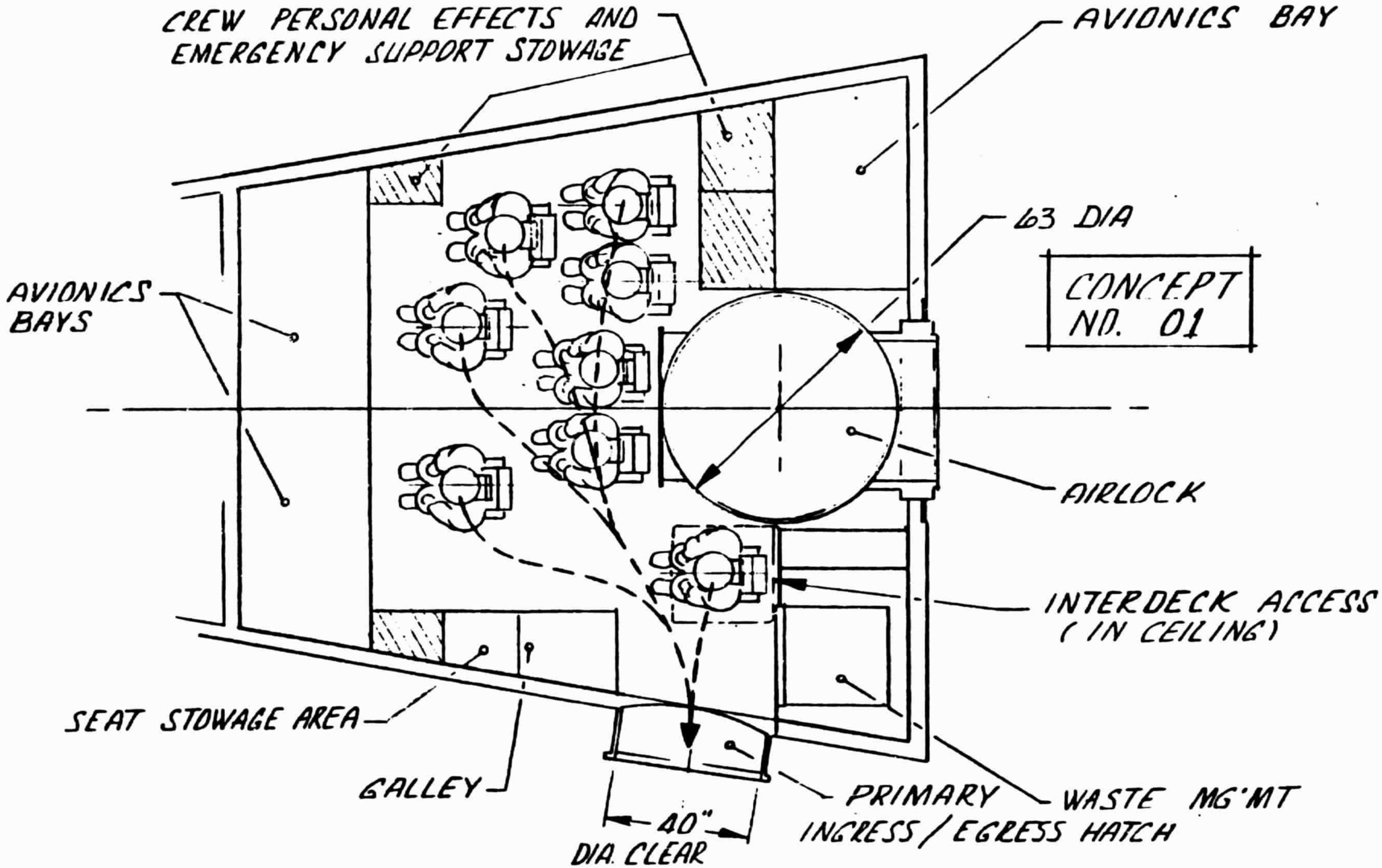


MID DECK
(LOOKING FWD)

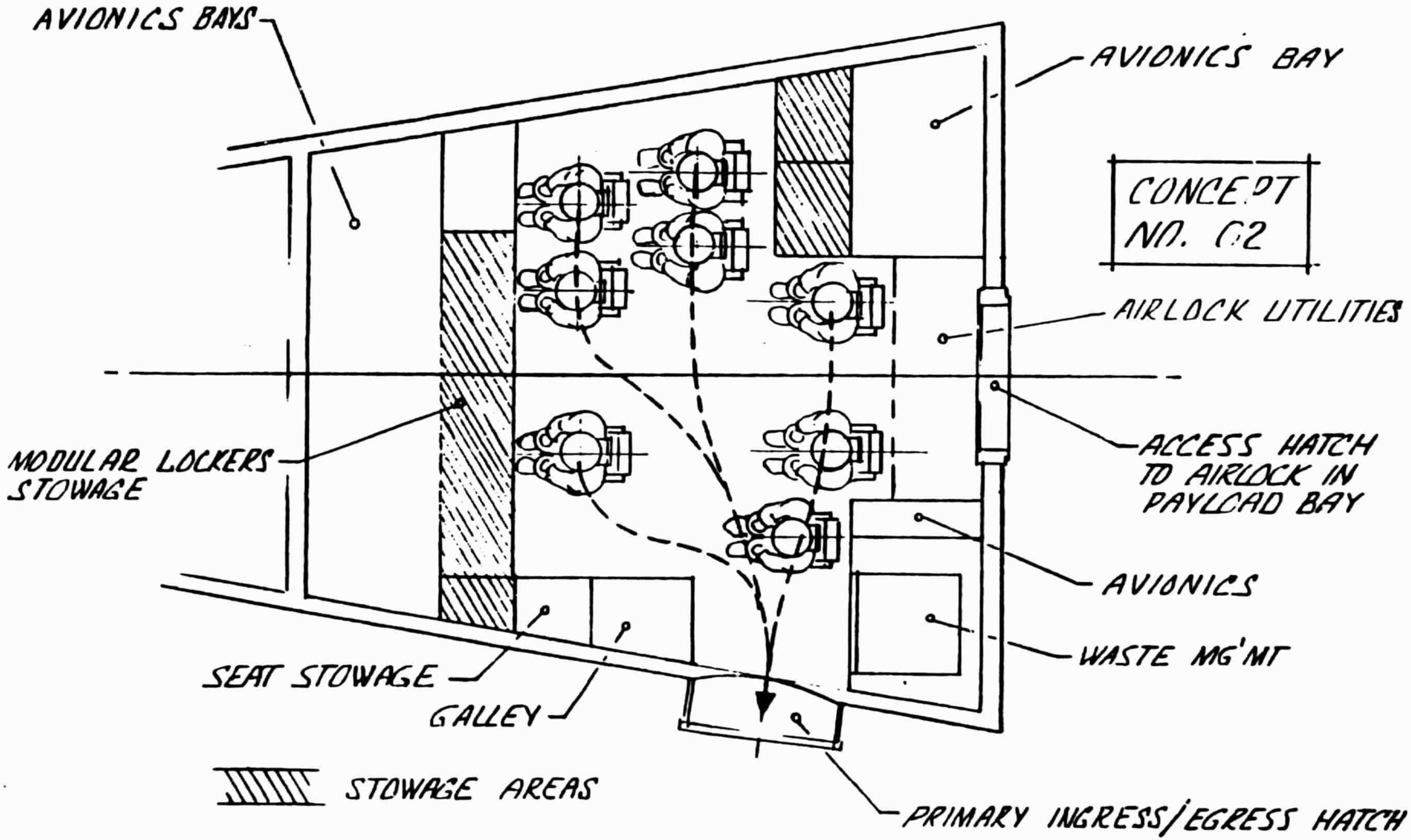
ORBITER MID-DECK - BASIC OPERATIONAL CONFIGURATION



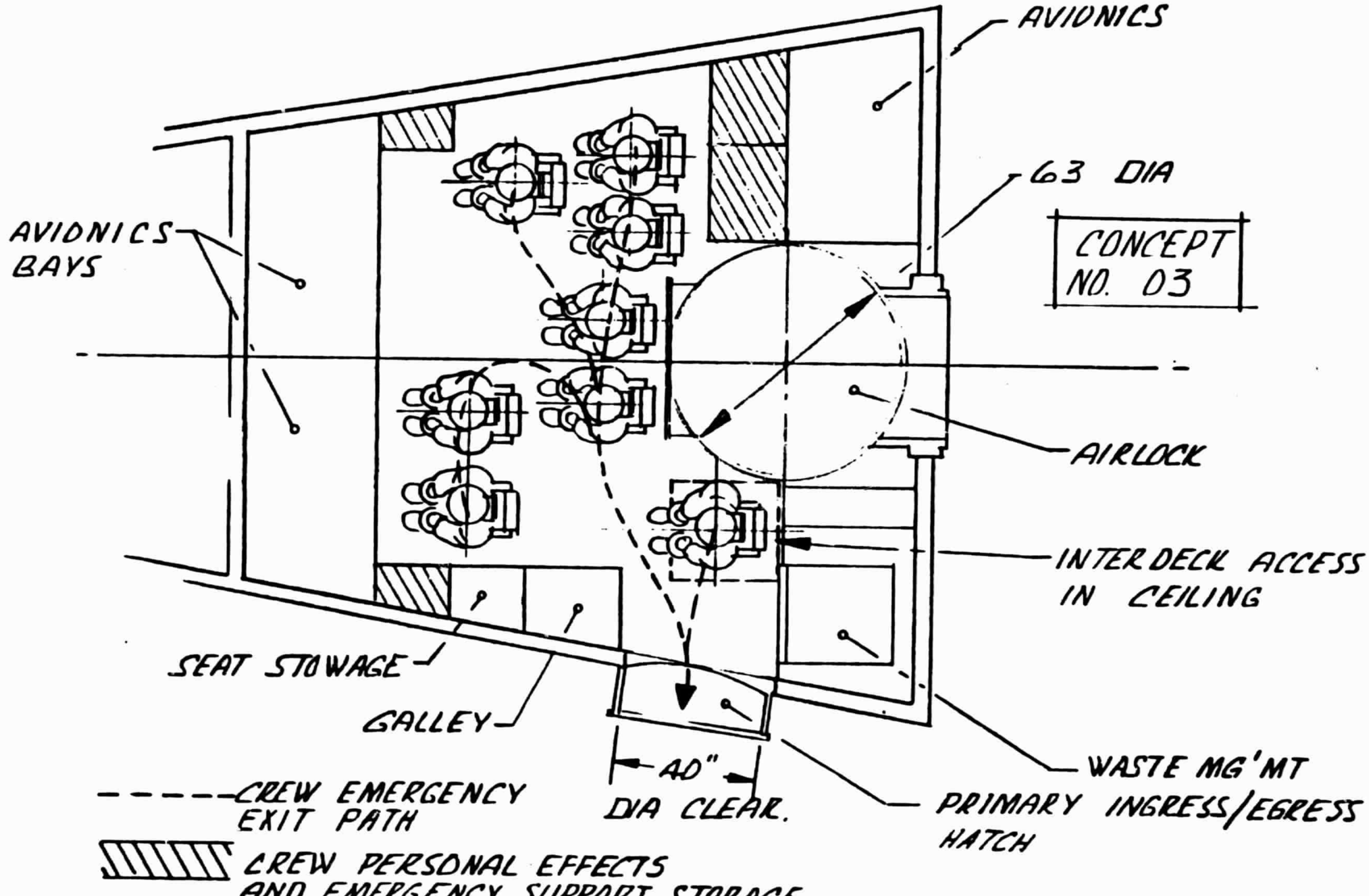
MODIFIED MID DECK WITH AIRLOCK



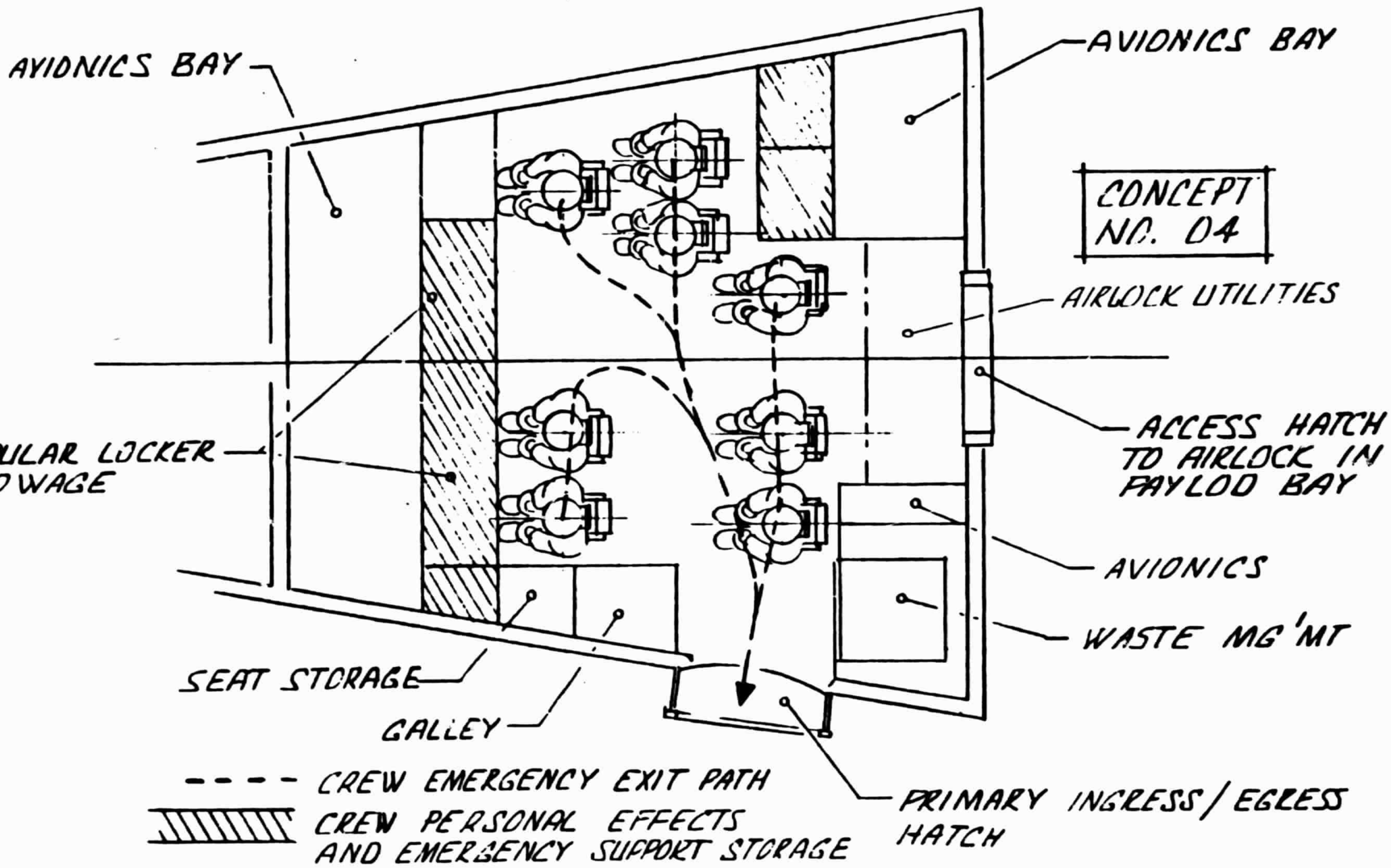
MID DECK WITH AIRLOCK IN CARGO BAY



MODIFIED MID DECK WITH AIRLOCK



MID DECK WITH AIRLOCK IN CARGO BAY



ENCLOSURE (4)

SOC/LOGISTICS MODULE EXCHANGE

There are four basic functions to be performed in the LM exchange activity:

(1) Deployment and restow of the LM from and to the payload bay.
(2) Berthing and releasing the LM to and from the SOC.
(3) Transporting the LM between the orbiter and SOC.
(4) Holding one LM while manipulating the other LM.

The equipments compatible with these functions are listed in matrix form in the enclosed charts.

Deployment and restow from and to the payload bay can be satisfactorily done by the PIDA with adequate clearance from a HAPA holding location. The PIDA can be considered the baseline equipment for this task.

Pickup and transport from the PIDA is obviously within the capability of the RMS. The RCM also has this capability regardless of the SOC docking quadrant if the RCM boom and cab rotation are oriented to a minimum-reach distance location.

Transport visibility with the RCM is somewhat better than with the RMS because of the rotation capability of the RCM cab as opposed to the fixed window area on the orbiter crew compartment and the RMS CCTV.

Three different exchange sequences were considered, using one transporter (either RMS or RCM). The first two are identical, except for the order of the activity. They involve a transport between the PIDA and HAPA, HAPA and SOC and PIDA. The third involves only a transport between the PIDA and SOC without requiring a HAPA. This can be done if the LM has an androgynous docking adapter to mate the old and new modules. This could be in the form of a new design, a set of PIDA petals, or an equivalent of the SOC interface. If it were the PIDA petals it could be the same ones used for payload bay withdrawl and restow, in which case the LM mating would be side-by-side rather than end-to-end.

The same three exchange sequences could be performed using two transporters with probably some savings in the activity timelines.

A comparison was made of the interfaces required for the different methods. Each of the methods requires the LM to incorporate a grapple fixture merely for transportation by the RMS or RCM end effector (EE).

The holding method (using HAPA) would require an interface for the EE, the PIDA, the HAPA, and the SOC. The HAPA interface could be a duplicate of either the PIDA or SOC to minimize the quantity to three. The PIDA duplicate would probably be simpler. The two transporter methods (no HAPA) would require the same three interfaces.

The module-to-module mount (side to side) could be performed with the same three interfaces.

Those three, EE, PIDA and SOC would satisfy the requirement for any of the module exchange sequences.

CONCLUSION:

The RCM is preferable from a visibility stand point. The module/module mating is preferable from the standpoint of minimizing flight support equipment. The RMS is preferable if reach were to become a problem. The choice of metnods is between the following:

(1) Using only one transporter

+ Uses only RMS or RCM
- Requires HAPA

(2) Using two transporters

+ Requires no HAPA
- Ties up both RMS & RCM

(3) Using module mating

+ Uses only RMS or RCM
+ Requires no HAPA
- Requires active latches on module interface to PIDA

On the premise that the HAPA will be available as a part of the orbiter inventory, the first choice (one transporter) should be considered baseline because it would not require any modification to the PIDA interface and it would not require both manipulators. Dependance on the RCM for the exchange operation could interrupt other SOC operations being performed at this time.

The baseline exchange scenario recommended is:

New LM	Old LM
(1) Deploy from P/L bay with PIDA	
(2) Move to HAPA with RMS	
	(3) Move from SOC to PIDA with RMS
	(4) Restow into P/L bay with PIDA
(5) Move to install on SOC with RMS	

EQUIPMENT/FUNCTION MATRIX

FUNCTION / EQUIPMENT	DEPLOY AND STOW	TRANSPORT	HOLD	BERTH AND RELEASE
RMS	SENSITIVE OPERATION	OK	OK	OK
PIDA	OK	NOT APPLICABLE	IN USE DURING HOLD	NOT APPLICABLE
HAPA	NOT APPLICABLE	NOT APPLICABLE	OK	NOT APPLICABLE
RCM	SENSITIVE OPERATION	OK	OK	OK
MODULE/MODULE	NOT APPLICABLE	NOT APPLICABLE	OK	NOT APPLICABLE

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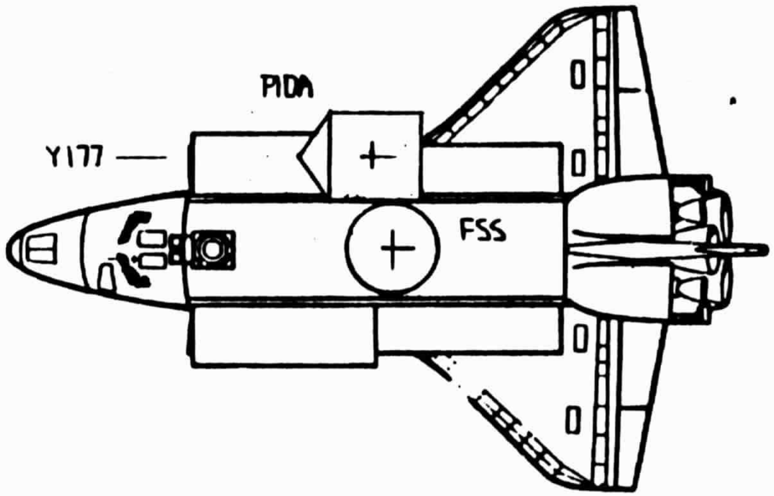
DEPLOY & STOW

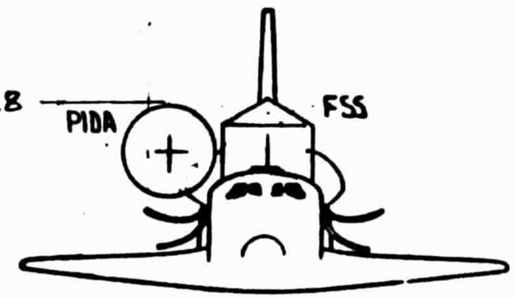
PIDA

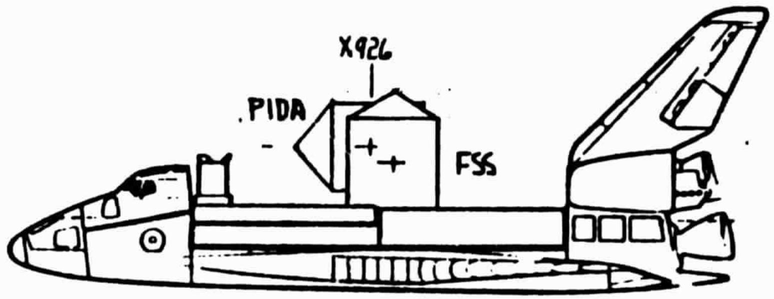
X FWD
Y STBD
Z HIGH
VERTICAL/HORIZONTAL END EFF.

FSS

X AFT
Y ℄
Z LOW
HORIZONTAL END EFF. ONLY





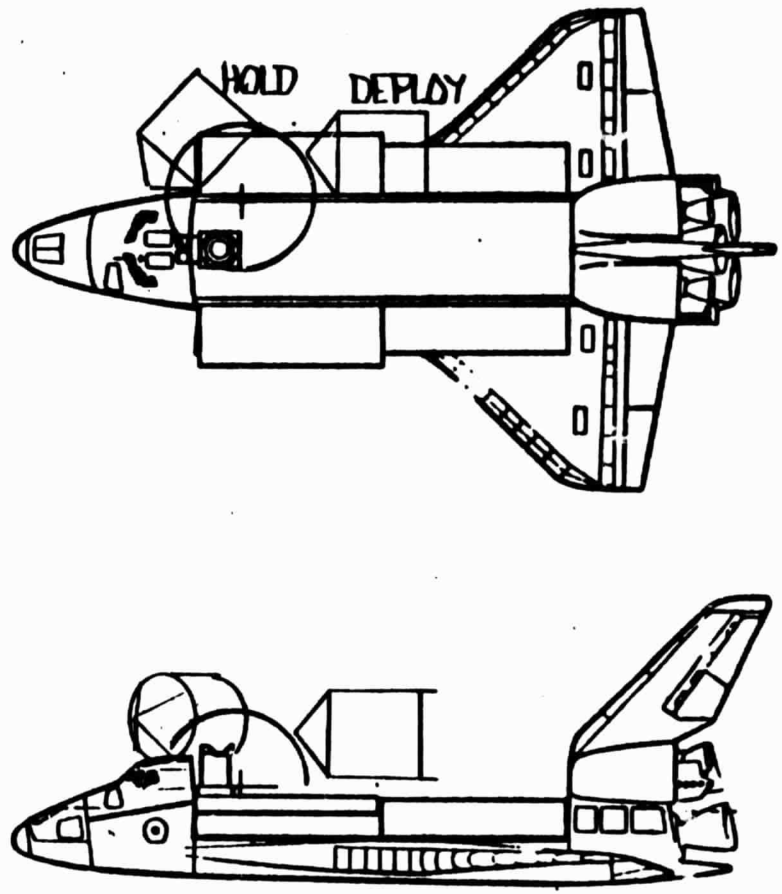


HAPA HOLDING

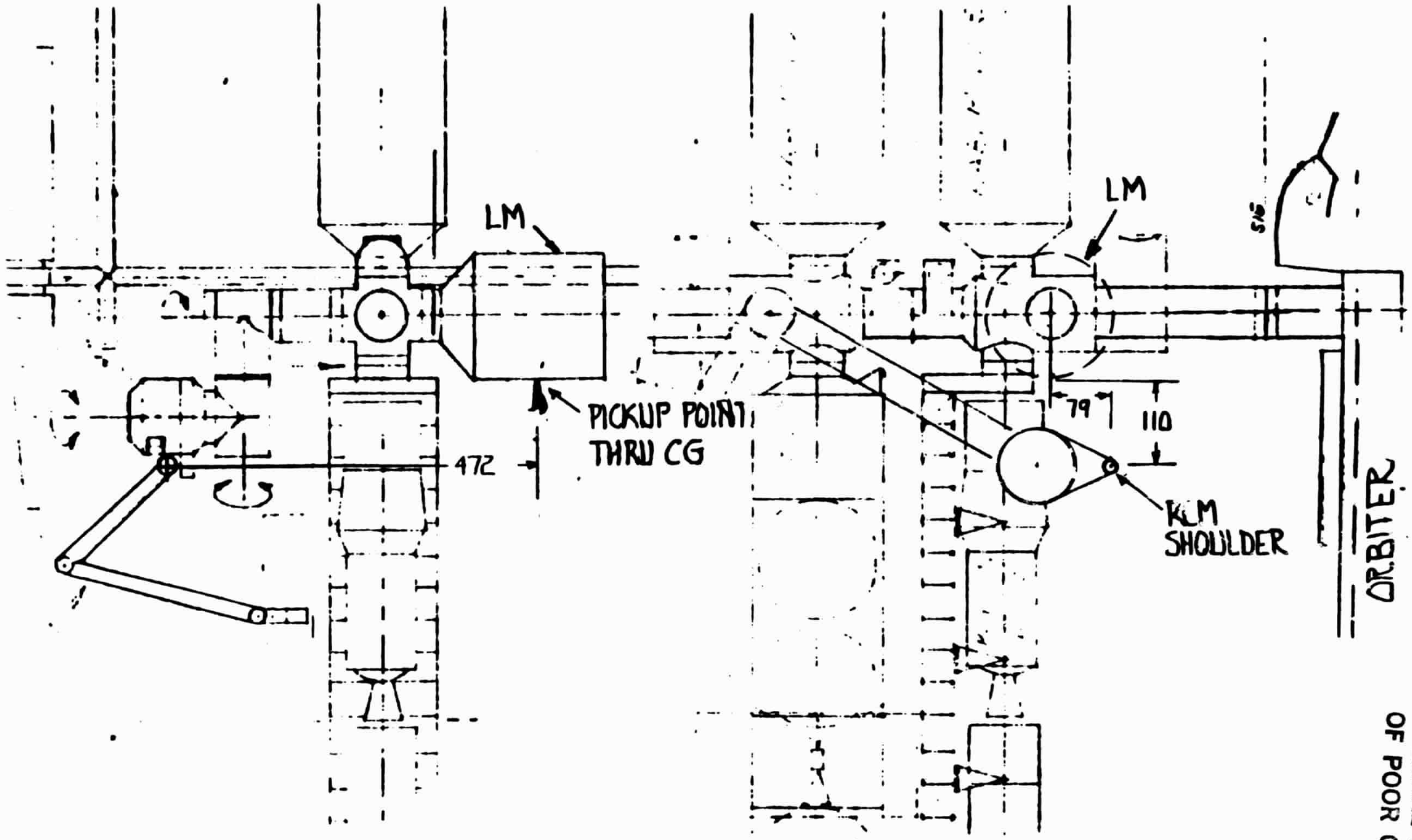
12 ft HAPA

ACCESSIBLE TO
RMS & RCM

DEPLOY & STOW
CLEARANCE

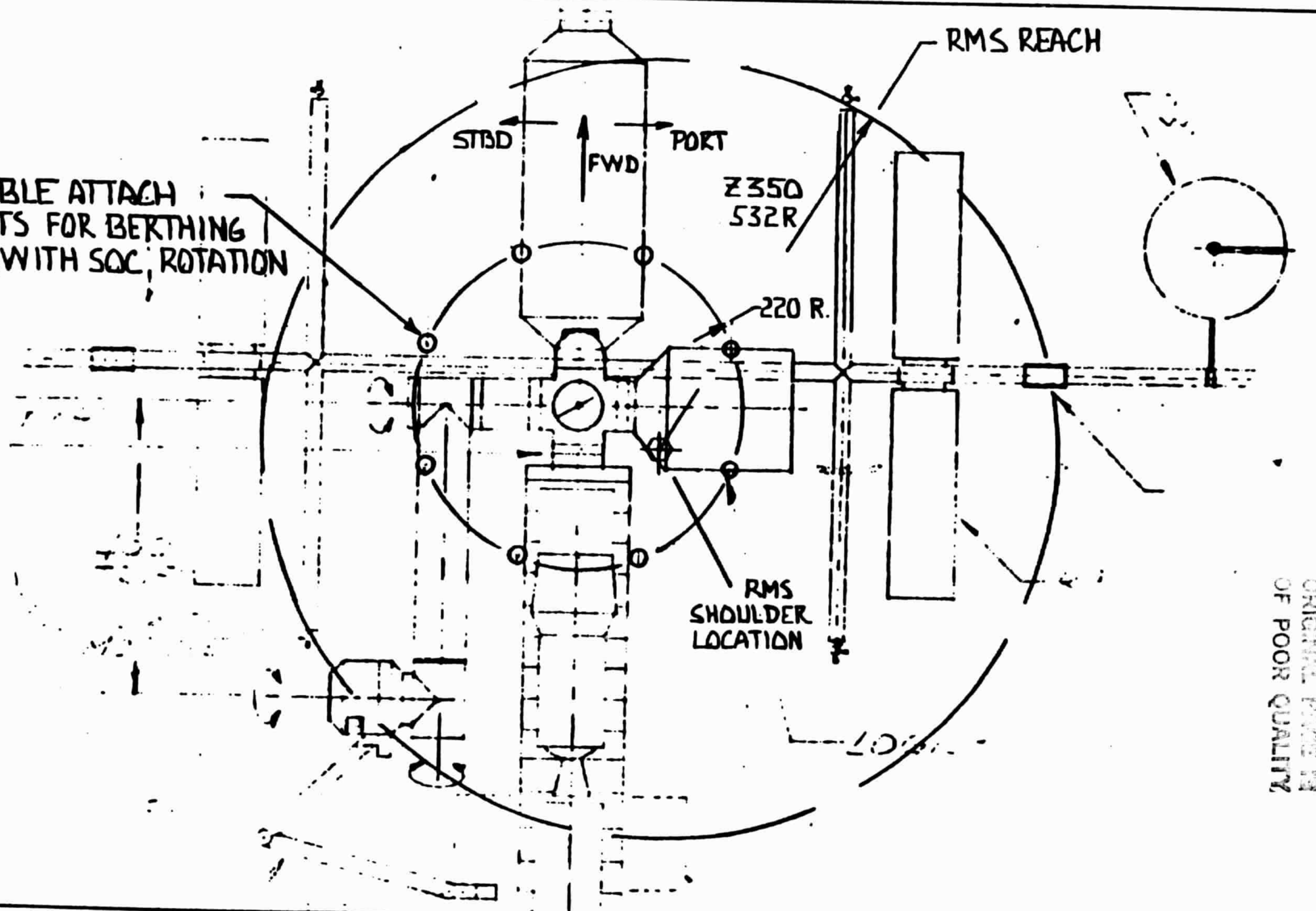


BERTHING LM
WITH RCM

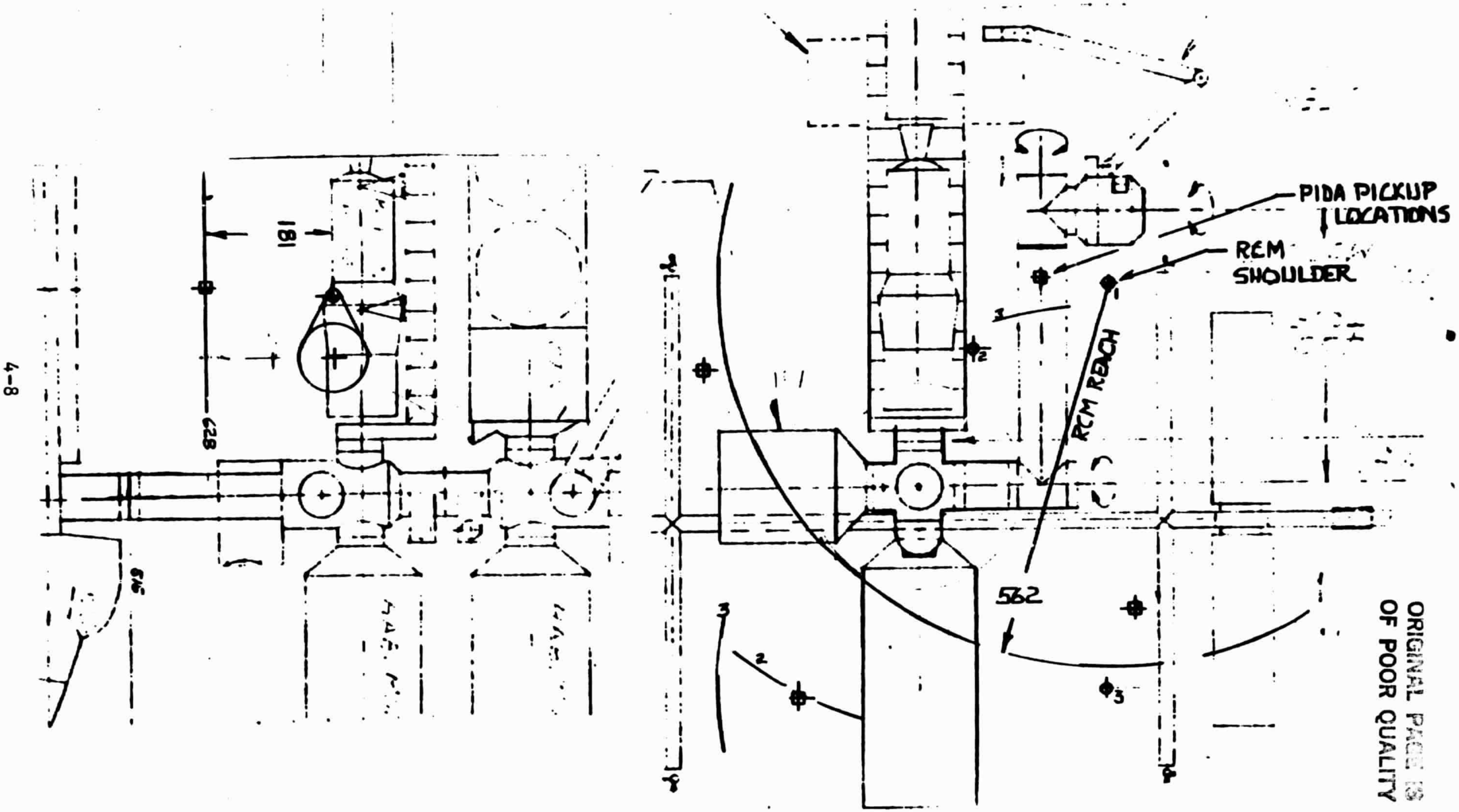


MAX REACH — $\sqrt{472^2 + 79^2 + 110^2} = 491$ RMS 529 TO WRIST-RCM ?

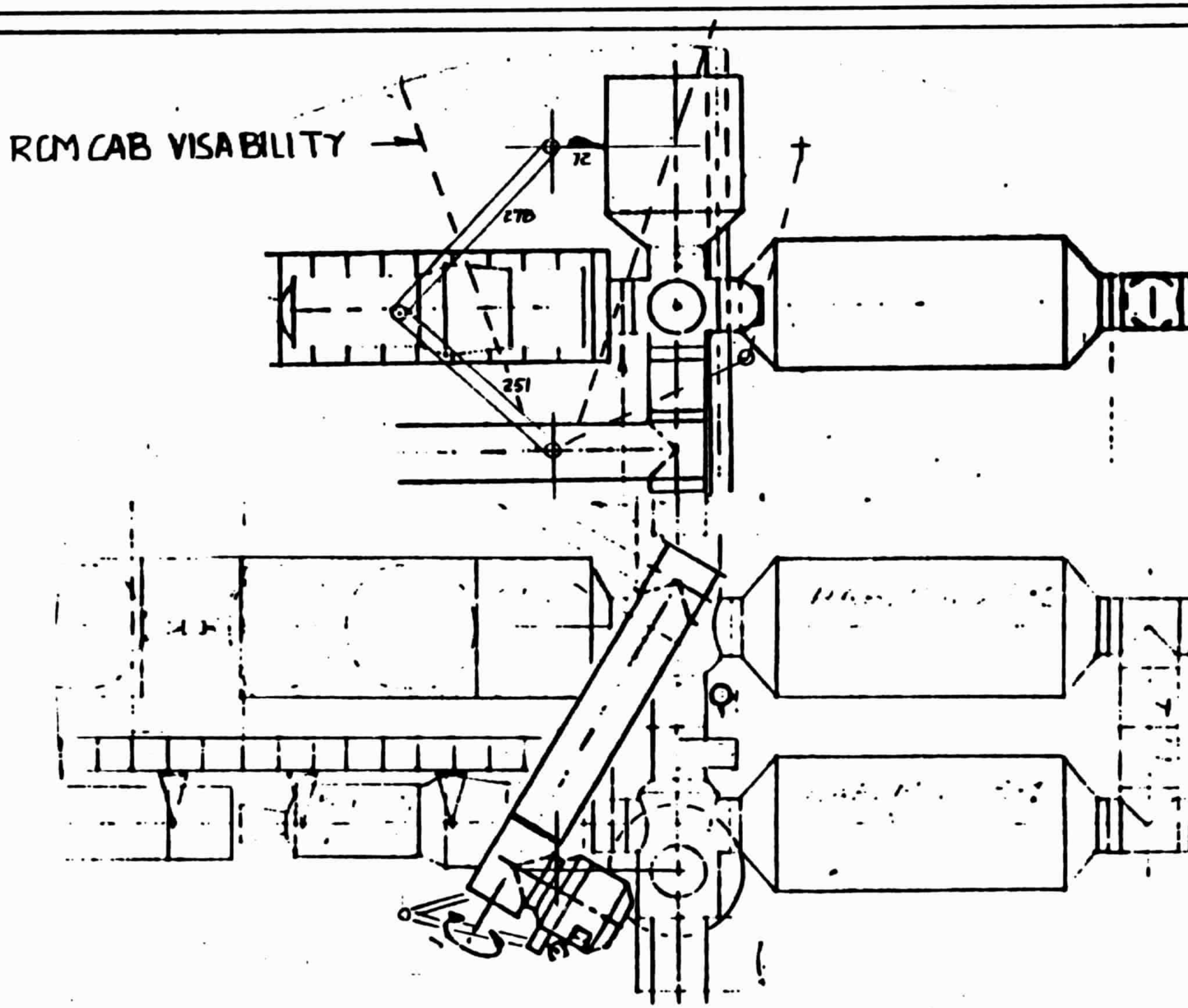
BERTHING USING RMS



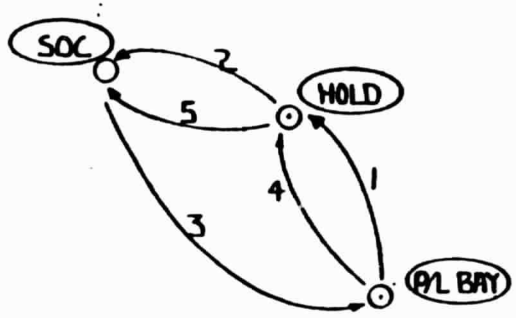
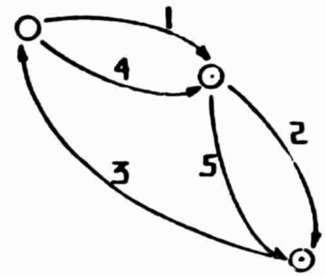
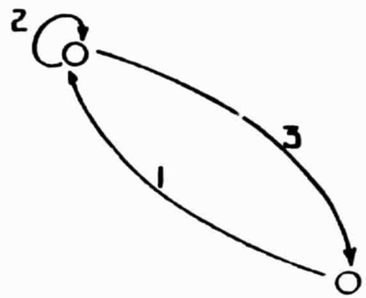
TRANSPORT FROM PIDA USING RCM



RCM VISABILITY



EXCHANGE SEQUENCE

HOLDING NEW MODULE (A-1)	1. NEW LM TO HOLD 2. MOVE TO SOC (TRANSPORTER) 3. OLD LM TO P/L BAY 4. MOVE TO HOLD (TRANSPORTER) 5. NEW LM TO SOC	
HOLDING OLD MODULE (A-2)	1. OLD LM TO HOLD 2. MOVE TO P/L BAY (TRANSPORTER) 3. NEW LM TO SOC 4. MOVE TO HOLD (TRANSPORTER) 5. OLD LM TO P/L BAY	
MATING OLD & NEW MODULES (B)	1. NEW LM TO SOC MODULE 2. EXCHANGE LM BERTHING 3. OLD LM TO P/L BAY (NO EXCESS TRANSPORTER MOVEMENT)	

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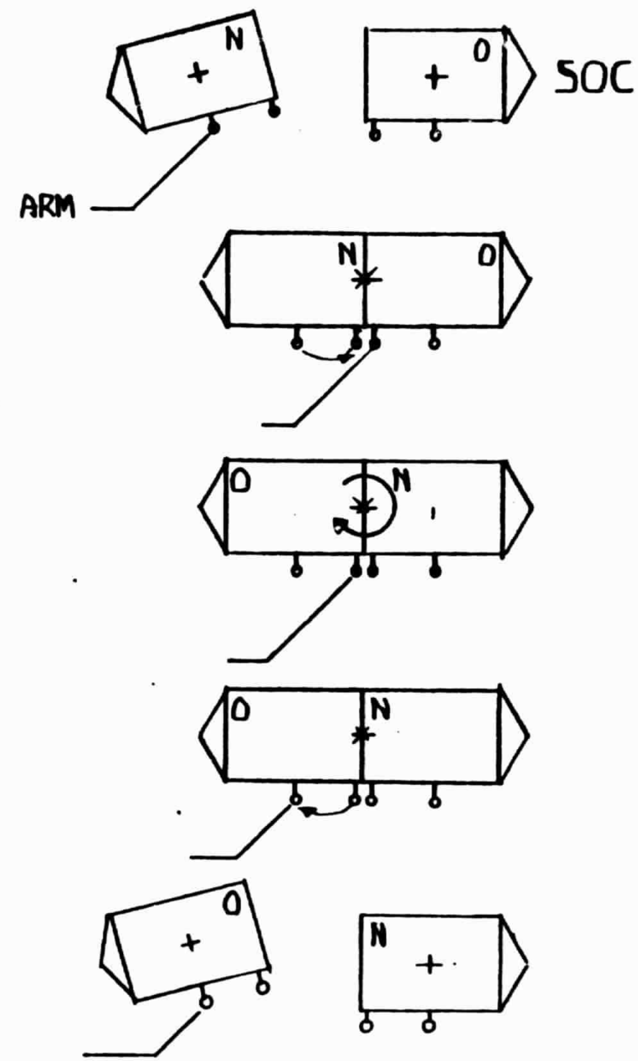
MATED-MODULE SEQUENCE
CONCEPT

1. TRANSPORT NEW LM TO MATING POSITION
2. MATE LM'S AND CHANGE PICKUP TO NEW CG LOCATION
3. RELEASE OLD LM - ROTATE LM PAIR - BERTH NEW LM TO SOC
4. CHANGE PICKUP TO NEW CG LOCATION
5. SEPARATE LM'S AND TRANSPORT OLD LM TO P/L BAY



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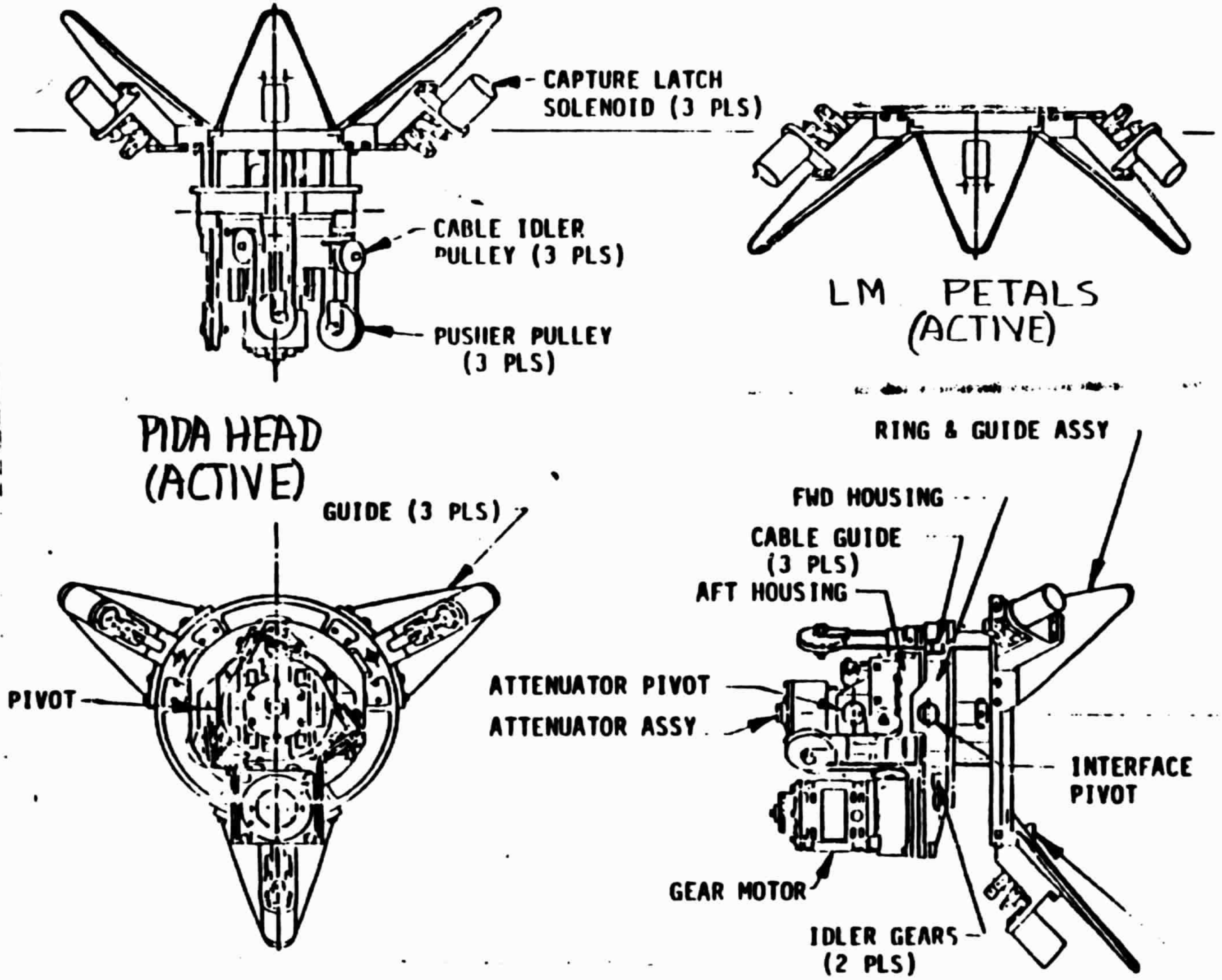
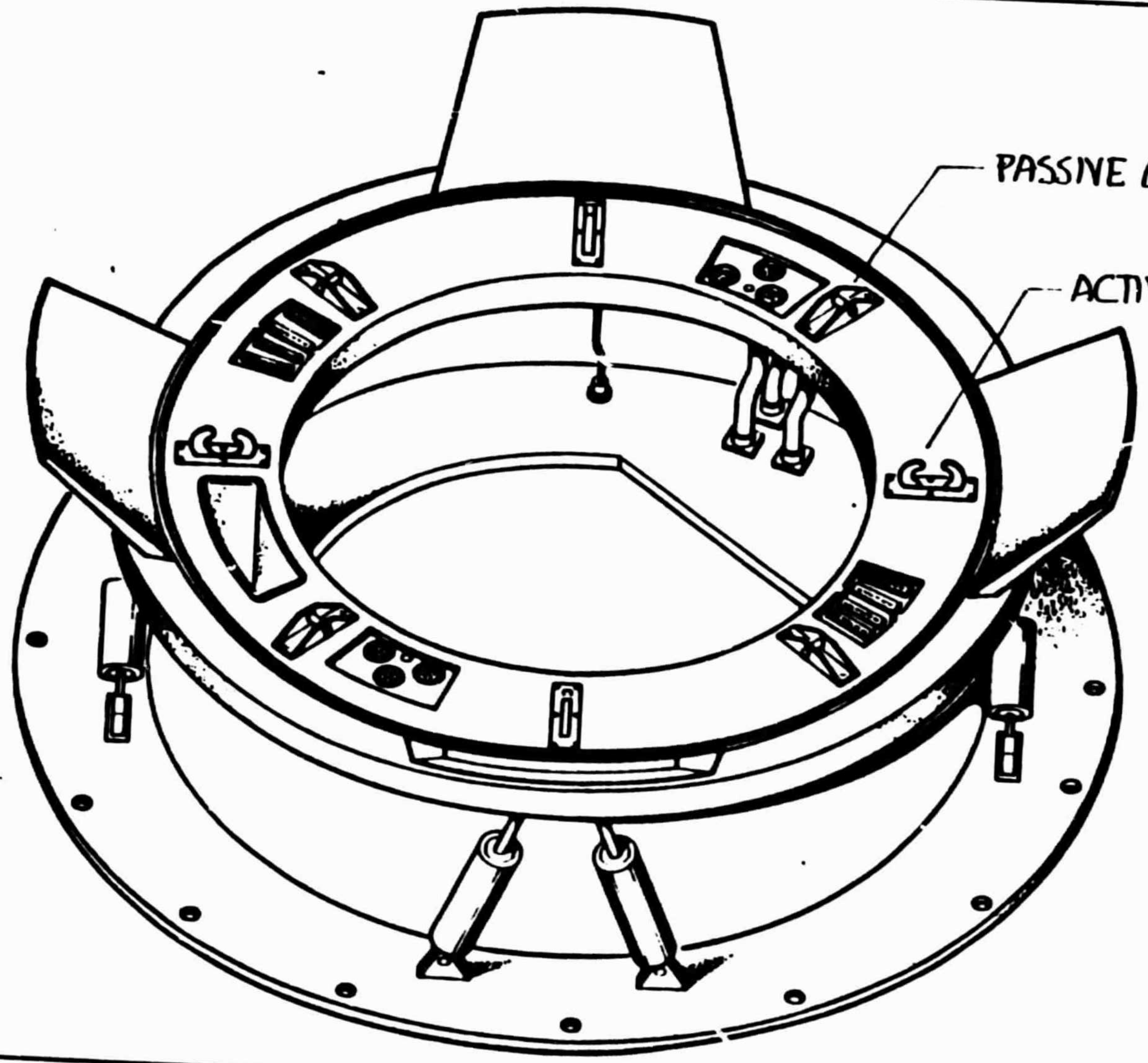
MODULE MATING LATCHES
PIDA INTERFACE MODIFICATION



SOC INTERFACE MODULE MATING OPTION



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EXCHANGE SEQUENCE

TWO TRANSPORTERS

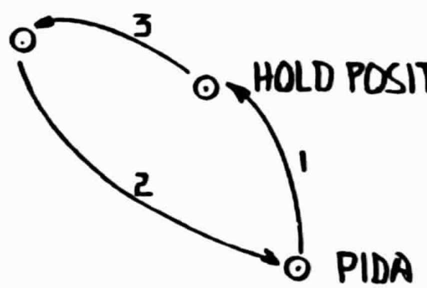
HOLDING NEW MODULE

(C-1)

1 RMS MOVE NEW LM TO HOLD

2 RCM MOVE OLD LM TO P/L BAY

3 RMS MOVE NEW LM TO SOC



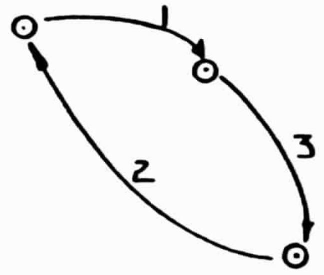
HOLDING OLD MODULE

(C-2)

1 RCM MOVE OLD LM TO HOLD

2 RMS MOVE NEW LM TO SOC

3 RCM MOVE OLD LM TO P/L BAY

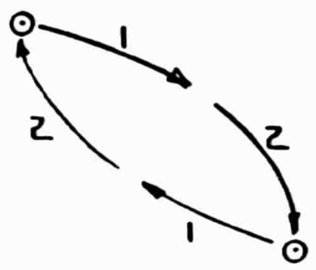


NOT HOLDING MODULES

(D)

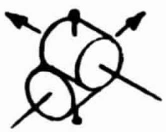
1. RMS PICKUP NEW LM FROM P/L BAY
AND
RCM PICKUP OLD LM FROM SOC

2. RMS MOVE NEW LM TO SOC
AND
RCM MOVE OLD LM TO P/L BAY



LOGISTICS MODULE INTERFACES

	INTERFACES REQUIRED					SIDE	END	
SINGLE TRANSPORTER WITH HOLDING								
1.	END EFF	PIDA	HAPA	SOC		3	1	(TOO MANY)
OR 2.	ENDEFF	PIDA-HAPA	SOC			2	1	
OR 3	END EFF	PIDA	HAPA-SOC			2	1	MOD HAPA
TWO TRANSPORTERS NO HOLDING	ENDEFF	PIDA	SOC			2	1	
SINGLE TRANSPORTER MODULE EXCHANGE								
1	ENDEFF	ENDEFF	PIDA	MODULE	SOC	3	2	(TOO MANY)
OR 2	ENDEFF	PIDA-MOD	SOC			2	1	MOD LATCH



GOOD - BAD

	GOOD	BAD
SINGE TRANSPORTER WITH HOLD	USES ONY ONE ARM	REQUIRES HAPA LONGEST TIME
TWO TRANSPORTERS	REQUIRES NO HAPA	TIES UP TWO ARMS (SCHEDULE) POSSIBLE INTERFERENCE
MODULE EXCHANGE	REQUIRES NO HAPA USES ONLY ONE ARM	REQUIRES ACTIVE LATCH MOD (DEV)

FOR	BEST METHOD
VISABILITY	RCM
EQUIPMENT	MOD EXCH
REACH	RMS

ENCLOSURE (5)

SOC/SUPPORT LOGISTICS CRADLE/INSTALLATION & CHECKOUT

The baseline SOC/orbiter orientation was assumed to be with the two habitation modules directed forward over the orbiter crew. It was also assumed that a single mounting interface would be used - for example, if the SLC were mounted in the payload bay on a version of the FSS, then the FSS mounting interface would be the same as the SOC mounting interface. Although two grapple fixtures may not be excessive, it was assumed that only one would be provided and in proximity to the SOC mounting interface. The three logistics cradle locations shown on Charts 2 and 3 are also considered baseline. Deployment from the payload bay was considered. If the SLC were installed on a rear-mounted FSS, the withdrawl of the SLC away from the FSS interface would result in a near interference with the SOC structure (approximately 1M). In addition, the RMS would only marginally reach to the grappie fixture next to the mounting interface. The RCM could easily reach this grapple position but the SOC structural interference problem would still be present.

If the SLC were installed on a forward-mounted FSS, there would be no significant interference problem but the RMS still has restricted movement. The RMS cannot articulate in the direction to undock the SLC from the FSS interface and the RMS elbow comes dangerously close to the logistics module during the deployment maneuver. Again, the RCM has sufficient articulation to make this withdrawl with adequate reach and without interference.

If the SLC were deployed from the payload bay by the PIDA prior to withdrawl, the RMS still has restricted movements in detaching the SLC from the PIDA interface, if the grapple fixture is at the aft end of the SLC, because of reach. With the grapple fixture at the forward end the RMS has sufficient reach and articulation (three extra degrees of freedom) to make this pickup.

During SLC exchange, it was assumed that the exchange berthing location would be between the PIDA and a HAPA. Here again, the RMS can make this transfer but with the same LM interface while the RCM can make the transfer without this restriction.

CONCLUSIONS:

The RMS elbow interference problem is with the LM, mounted on the orbiter port-side. If the baseline SOC mounting were rotated 180° the RMS and RCM could basically perform the same functions. However, with the SOC as presently baselined, the installation and changeout of the SLC should be dedicated to RCM activity.

The installation scenario, then, would be:

(1) Deploy with PIDA or front mounted FSS.
(2) Pickup and transport with RCM.
(3) Install with RCM.

The exchange scenario would be:

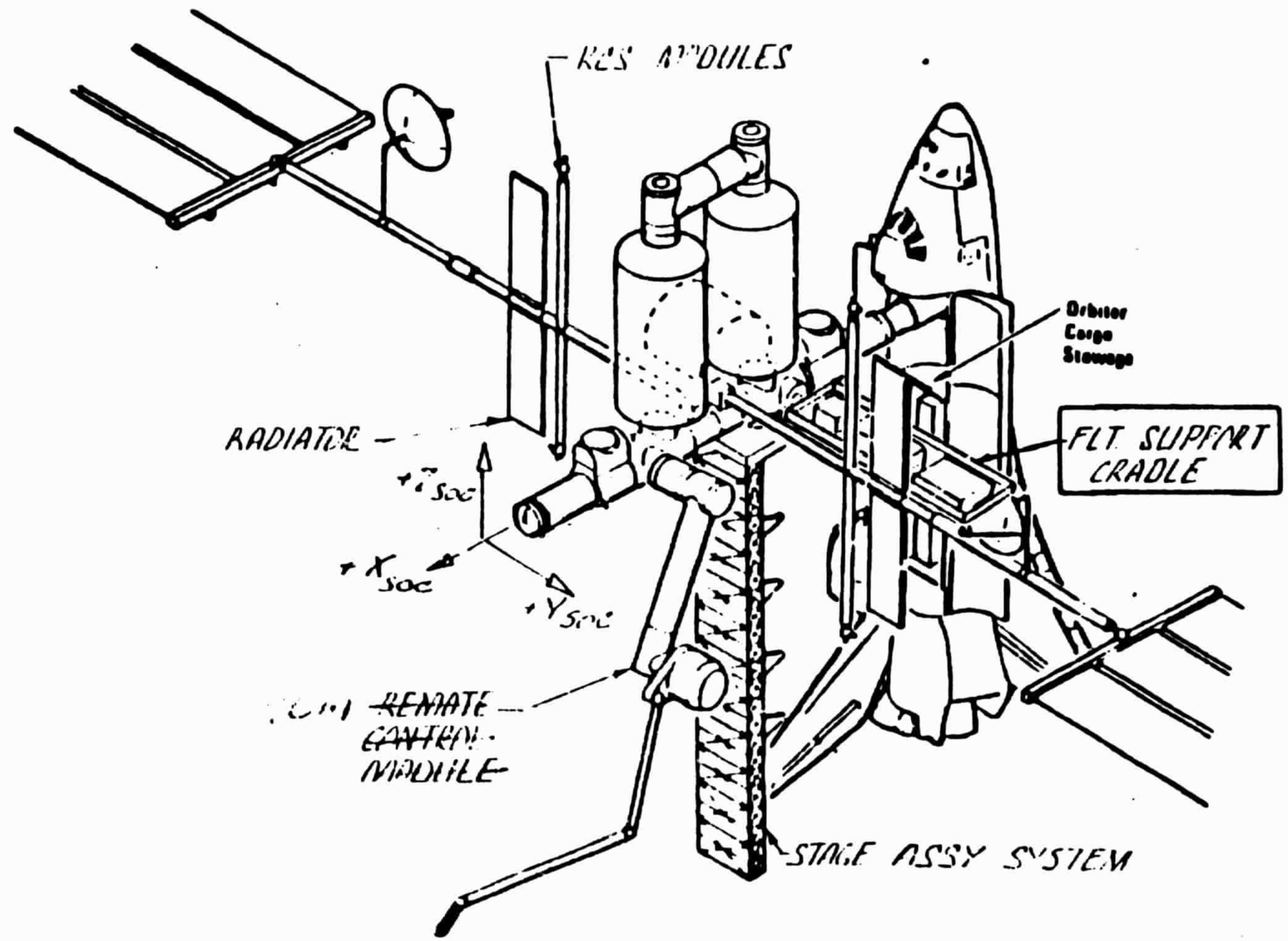
(1) Deploy new module with PIDA or front mounted FSS.
(2) Detach old module from SOC, transport and berth to HAPA with the RCM.
(3) Pickup new module from PIDA or FSS, transport and install on SOC with RCM.
(4) Return and transfer old module from HAPA to PIDA or FSS with RCM.
(5) Restow old module to payload bay with PIDA or FSS.

The sequence of the exchange scenario could be reversed with no effect on timelines, total movements or freedom of motions:

(1) Deploy new module.
(2) New module from PIDA to HAPA.
(3) Old module from SOC to PIDA.
(4) New module from HAPA to SOC.
(5) Restow old module.

Since the PIDA is presently defined as a universal deploy/restow piece of equipment and the FSS concept is defined as special-purpose equipment, it is recommended that the installation/changeout functions be baselined around the RCM and PIDA combination, with the HAPA as the exchange holding device.

SOC - LOGISTICS CRADLE INSTALLATION



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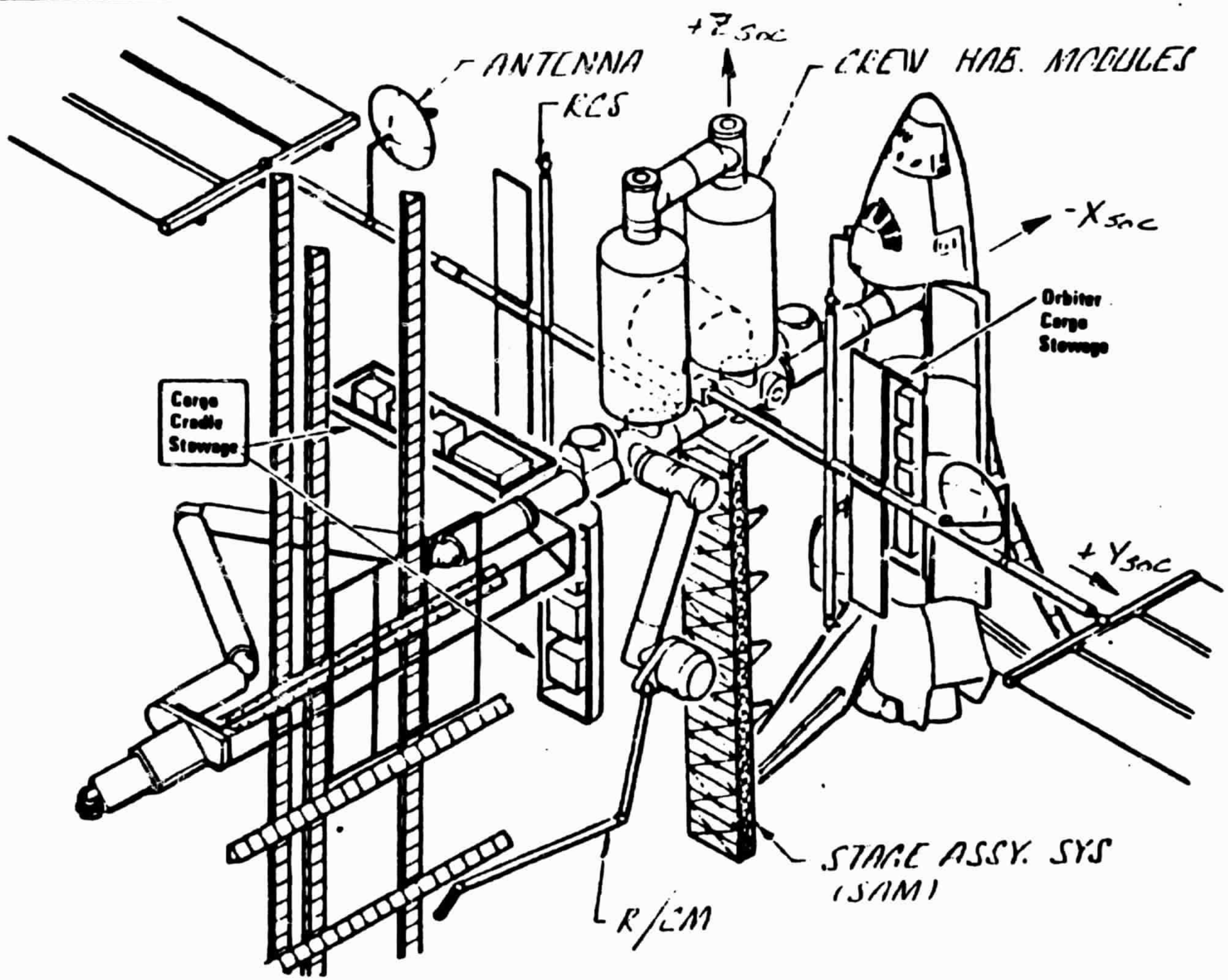
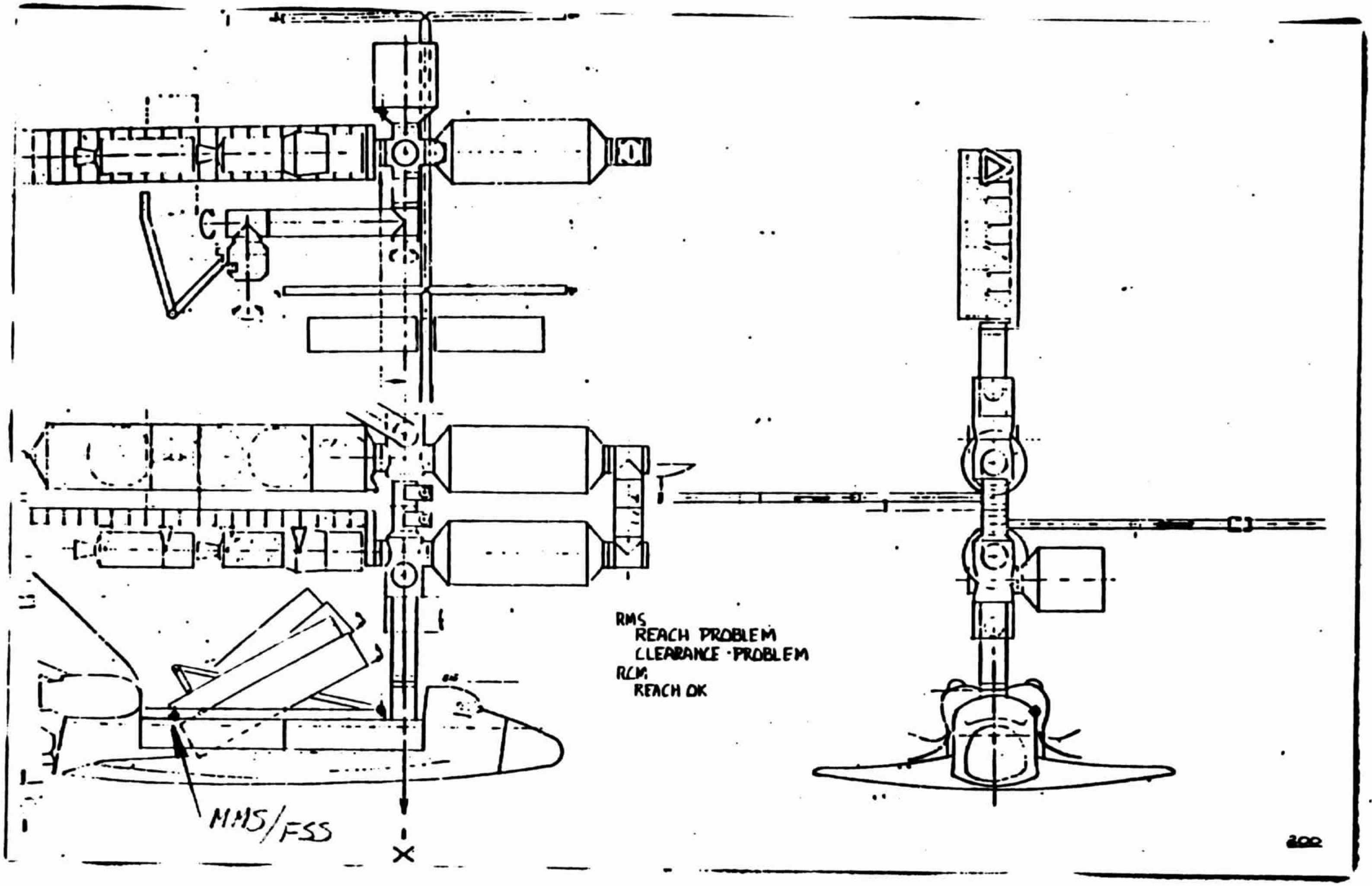
SOC/ORBITER CONFIGURATION



MMS/FSS DEPLOYMENT CONCEPT - AFT LOCATION



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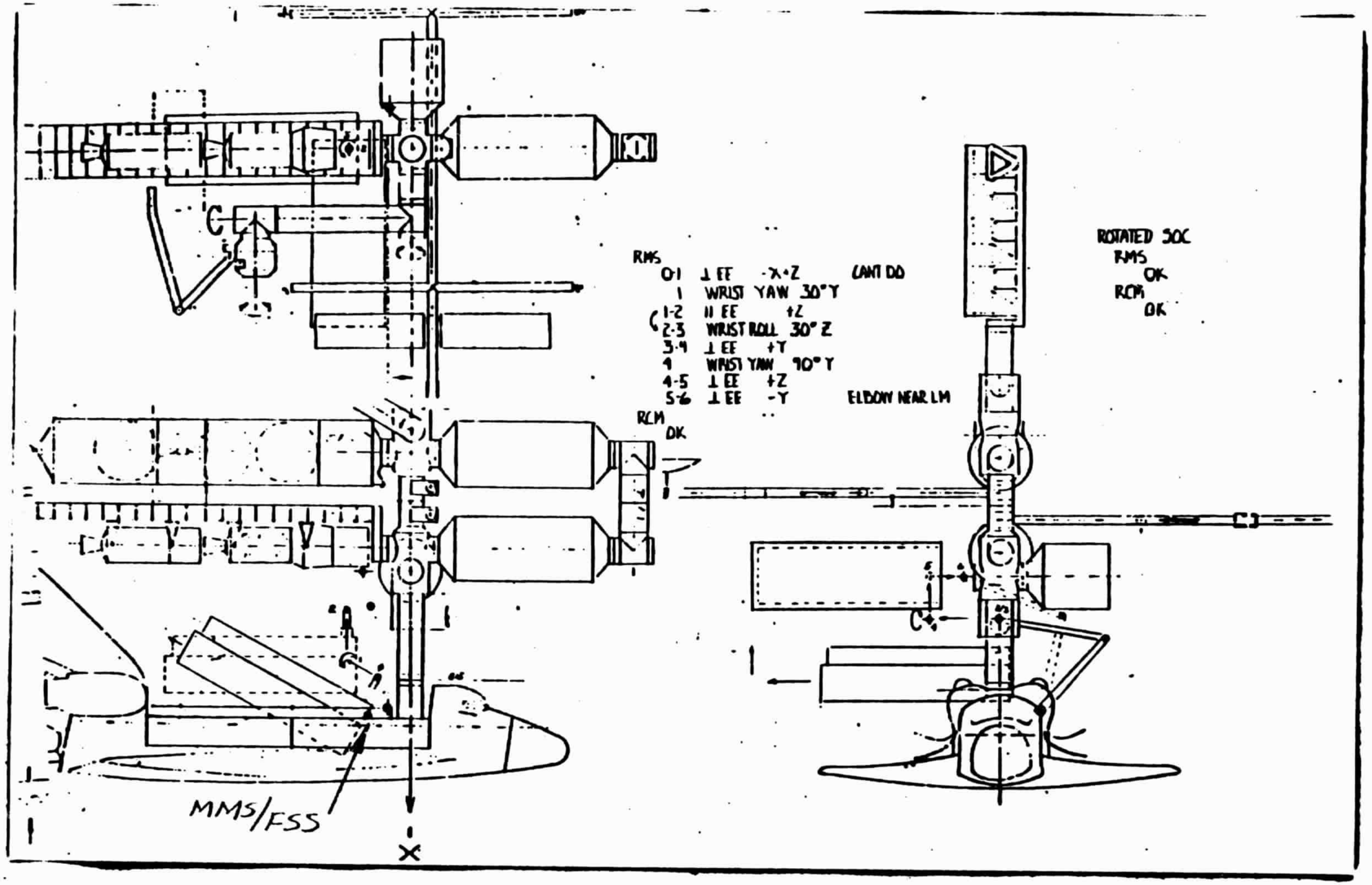
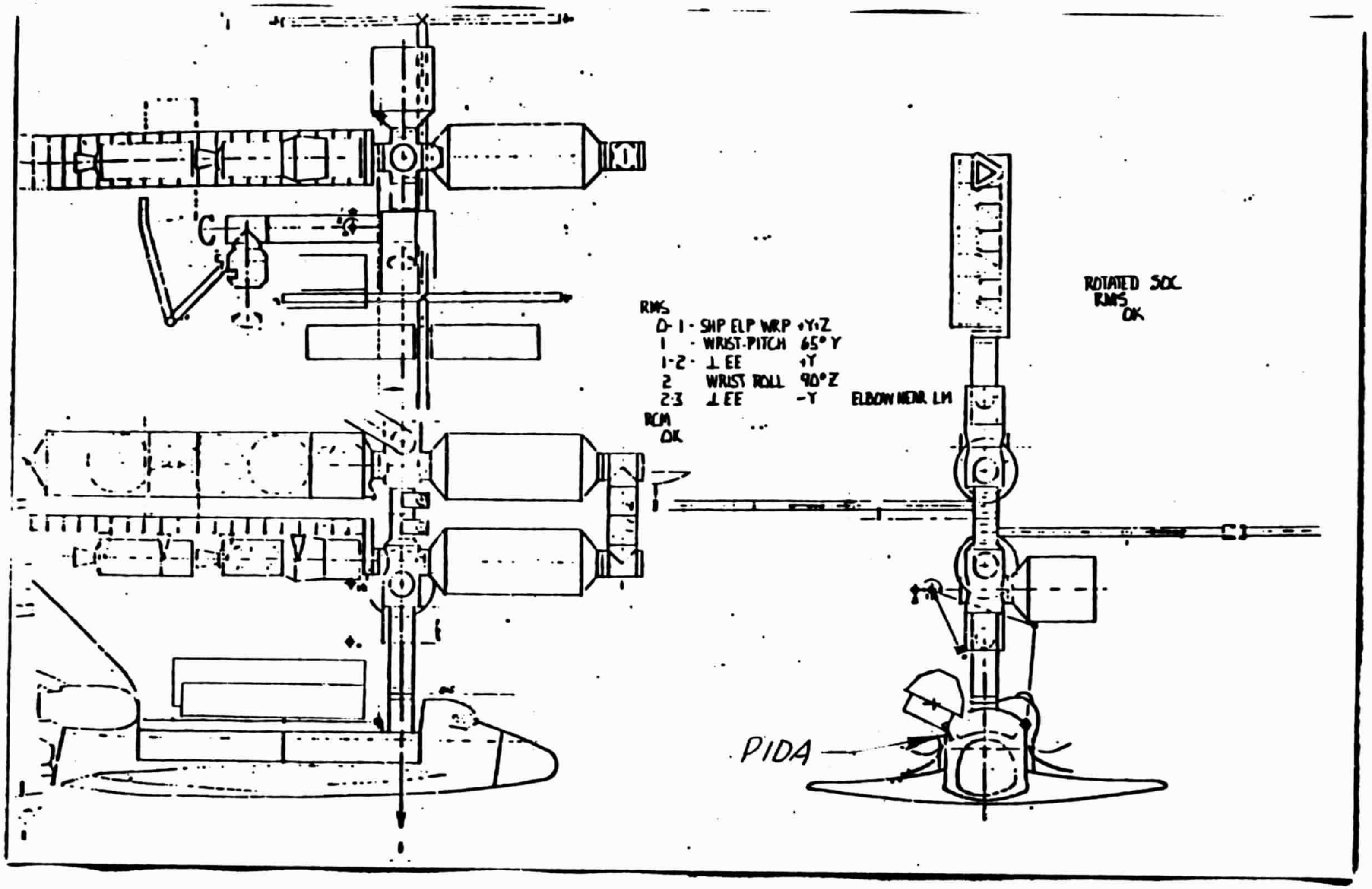
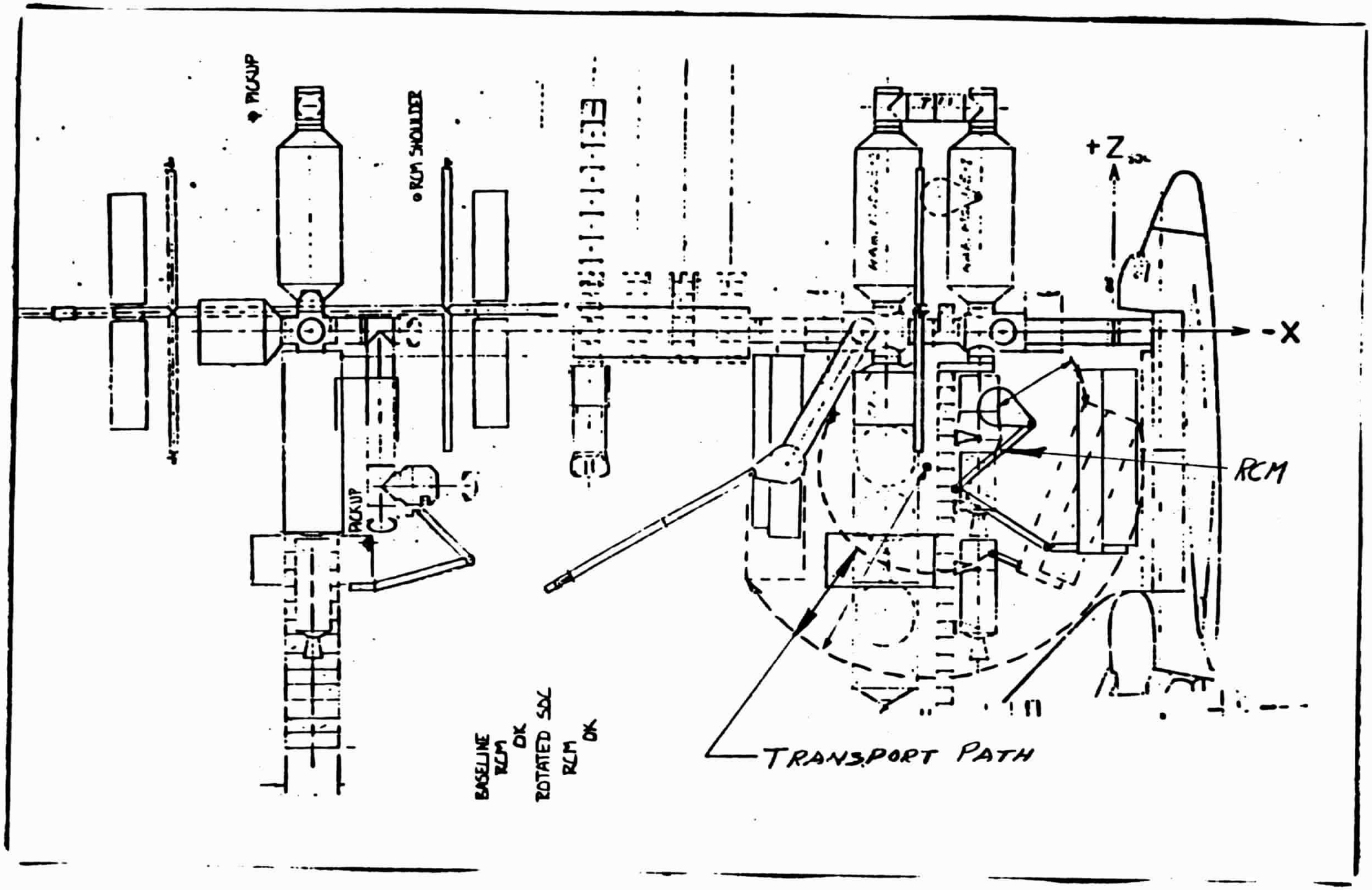
MMS FSS DEPLOYMENT CONCEPT - FWD LOCATION



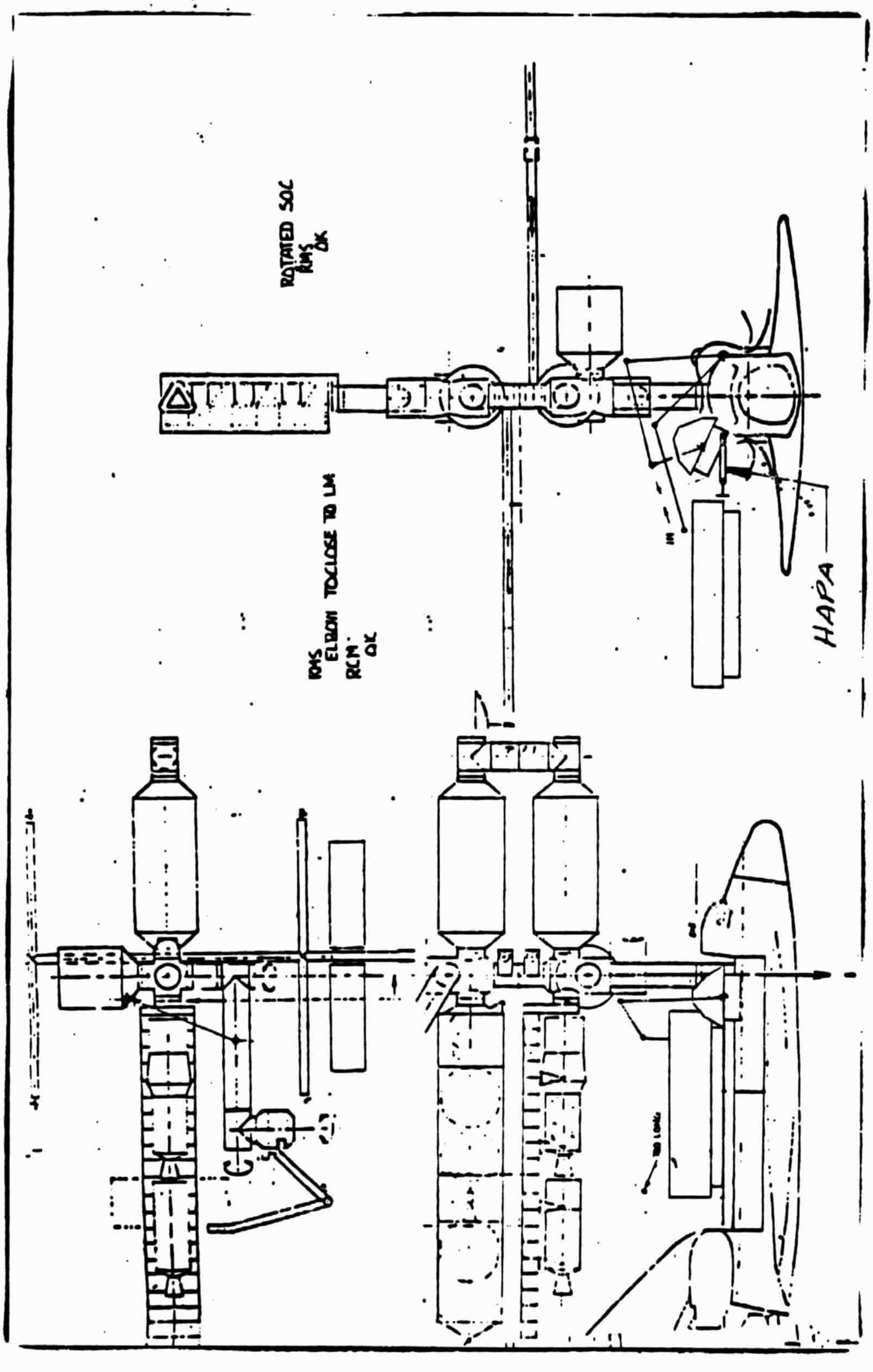
PIDA DEPLOYMENT CONCEPT



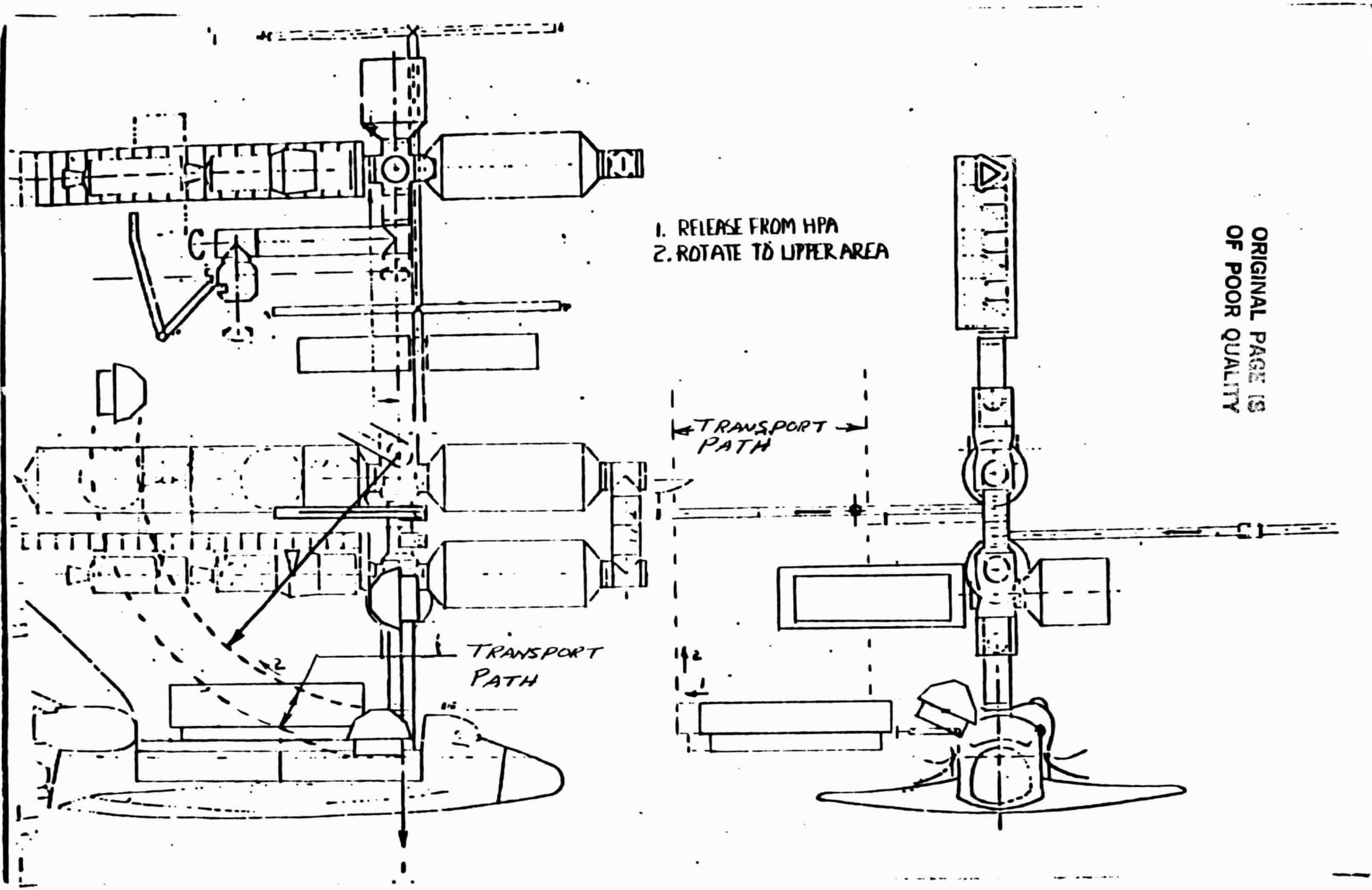
SOC RCM TRANSPORT CONCEPT



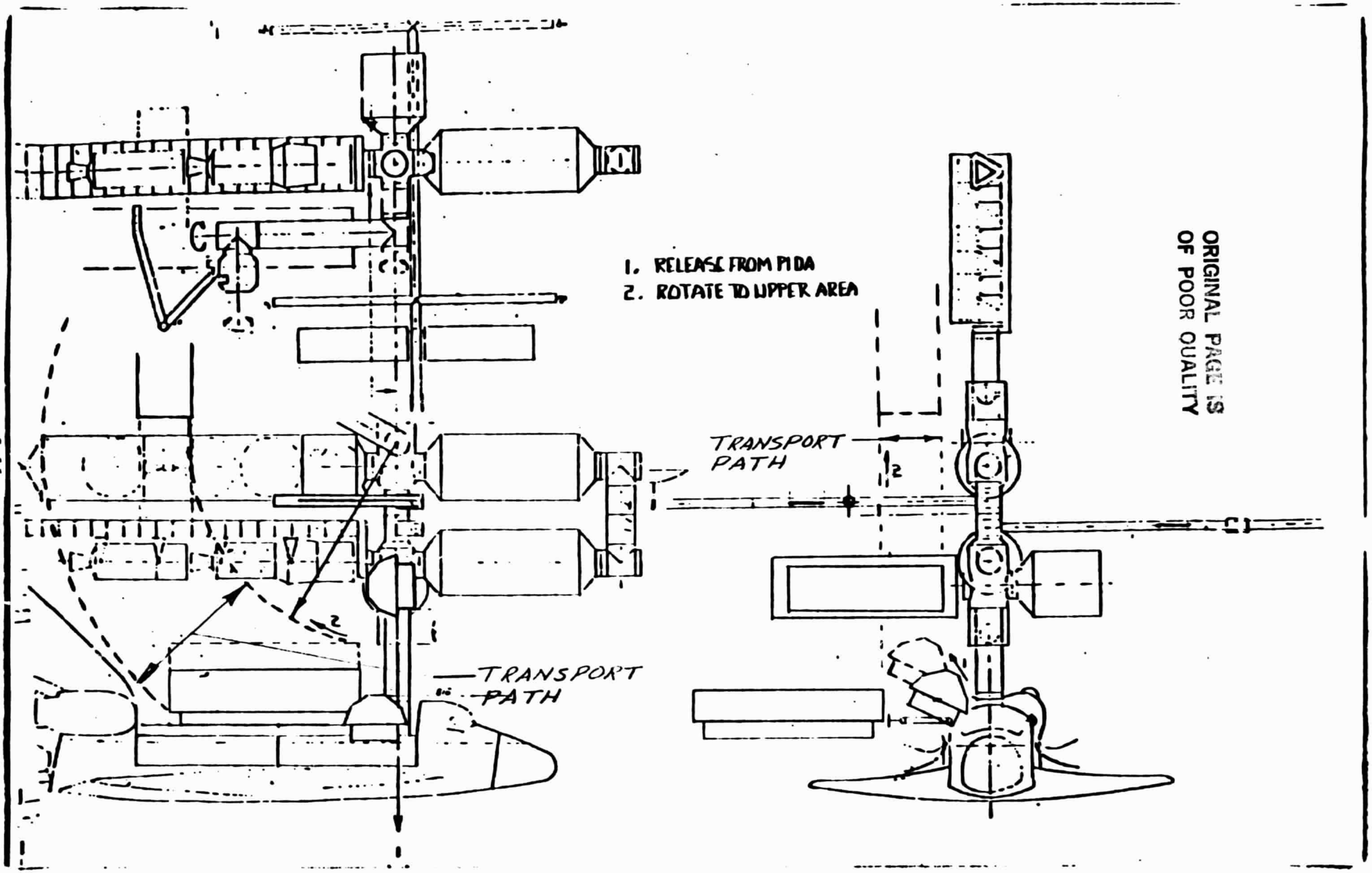
HAPA Holding Concept



RCM TRANSPORT FROM HAPA



RCM TRANSPORT FROM PIDA



SUMMARY

REAR MOUNT FSS	CLEARANCE PROBLEM	
FWD MOUNT FSS	RMS CANT WITHDRAW	RCM CAN WITHDRAW
	BOTH OK WITH ROTATED SOC	
PIDA MOUNT	RMS CLEARANCE PROB	RCM CAN WITHDRAW
	BOTH OK WITH ROTATED SOC	
PIDA TO HAPA EXCHANGE	RMS CLEARANCE PROB	RCM CAN EXCHANGE
	BOTH OK WITH ROTATED SOC	
LOWER CRADLE INSTALLATION	RMS OK BUT NEAR LIM	RCM OK
	BOTH OK WITH ROTATED SOC	
UPPER CRADLES INSTALLATION	RMS CANT REACH	RCM OK

<u>RECOMMENDATION FOR BASELINE</u>

PIDA DEPLOYMENT
HAPA HOLDING
RCM TRANSPORT